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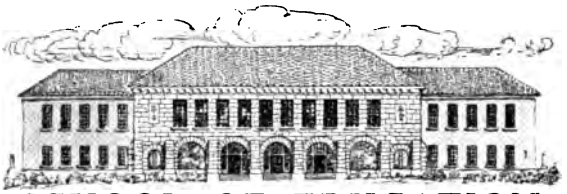

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CIVIC AND ECONOMIC BIOLOGY

ATWOOD

CIVIC AND ECONOMIC BIOLOGY

BY

WM. H. ATWOOD, M.A., M.S.
Milwaukee State Normal School

364 ILLUSTRATIONS

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P. BLAKISTON'S SON & CO.
1012 WALNUT STREET

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PREFACE

This book is written primarily for boys and girls of the sophomore year of high schools and academies. It owes its existence to inspiration given by such students, and is the outgrowth of several years of pleasant fellowship with them.

The subject matter is divided into seven units which are given in the best order for a year's course, beginning in September. If the course begins in midwinter the versatile teacher will rearrange the work to suit the needs of the class. Each study is complete in itself and constitutes a lesson. This does not mean that there should be but seventy meetings of the class, for many meetings will be in the field or laboratory. It merely means that the material for seventy recitations is outlined in the book. If the book is to be used in a half year course, omissions should be made in order to allow time for laboratory and field projects.

The teaching of elementary science in the freshman year has, in recent years, become so popular that it is a matter to be considered in the preparation of a book for sophomore students. It is no longer proper to write a book which is designed for either the freshman or sophomore year. It will not be advanced enough to hold the interest of students who have had an introduction to the sciences. The author has given this matter considerable thought, and has prepared a text which treats topics for which the sophomore is prepared; but he has not lost sight of the fact that there will be some students who have not taken the course in elementary science. Therefore, the subject-matter is arranged in the most flexible form possible. The study on cell division is outlined in detail, but it is not assumed that all students will master the facts equally well. This is also true of the studies on the life history of the moss, fern, pine, and flowering plant. The studies on embryology are intended to merely present an outline which must be used by the teacher with the interest and ability of the class in mind. The author expects that the teacher will make omissions and additions where it is best to make them.

Wise teachers will not make the text a screen of interference through which the student must study nature, but will arouse in their pupils such interest that they will work spontaneously for the love of it. Forced knowledge in nature study will avail but little. The time is passed when a teacher is expected to grind all students through the same mill. Is there any reason except precedent why all students should work on the same thing at the same time? Let each student do that in which he takes delight. All children love nature. When the bee is presented for study some may dissect it, some may make drawings of its parts, some may work up reports, some may study the life history, some may learn its habits, others may investigate its economic importance; and thus all will be interested; and each will contribute something to the lesson. The text is to be read by all and furnishes an outline for the quiz which closes the study.

All of the great principles of life are common to plants, animals, and man. Therefore, if the subject of biology is divided into a half year of botany and a half year of zoology there is danger that these truths may be neglected or improperly appreciated. Digestion, respiration, irritability, reproduction, heredity, evolution, etc., are common to both kingdoms and should be so studied. It is largely for this reason that the course should be a unit and should be called BIOLOGY.

Civic and economic biology is the study of the life of the earth in relation to man and his institutions. The author does not object to studying the æsthetic aspects of bilogy but is convinced that the phases to emphasize in a high school course are the practical ones. Scientific research has revealed the causes of the diseases of plants, animals, and people; it has shown how we may have better grain, fruit, vegetables, and domestic animals; hybridization and selection have given us hundreds of beautiful flowers, vines, and shrubs to make our homes and parks more attractive; students of eugenics and euthenics have shown us how to improve mankind. Biologically, as well as physically, the environment of man has been greatly changed during the past century. We are living in a new age, and those who have the best understanding of it are in a position to get the most profit and pleasure out of it, and to be of the greatest service to their

fellows. Furthermore, civic progress requires the coöperation of the majority of the people of the community, and coöperation without knowledge is impossible.

It is the hope of the author that the courses founded on this book will prove to be a valuable contribution to the lives of students and to the communities in which they live.

WM. H. ATWOOD.

ACKNOWLEDGMENTS

The students who have consciously and unconsciously contributed valuable ideas to the making of this text are too numerous to mention by name.

The author acknowledges with pleasure the debt he owes to the following educators for reading the manuscript and giving valuable advice: Ida M. Atwood, Welz E. Boren, Grant Cook, E. O. Finkenbinder, Chas. B. Gates, Jno. Giesen, Marjorie Jacques, Frank A. Maas, Amelia McMinn, Frank J. Mellenkamp, Alvin L. Throne, Harvey A. Uber.

The author is also grateful to the following publishers for permission to use various illustrations: D. Appleton & Co., P. Blakiston's Son & Co., The Bobbs-Merrill Co., Ginn & Co., Henry Holt & Co., The Macmillan Co., A. I. Root & Co., The Wisconsin Farmer, and The Journal of Heredity.

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CIVIC AND ECONOMIC BIOLOGY

UNIT I. HOW PLANTS AND ANIMALS LIVE

THE PROBLEMS OF LIFE

1. INTRODUCTION

Man can not answer the problem, "What is life?" nor the question, "What is electricity?" but science has discovered many interesting things about both.

Biology (Gr. *bios* = life + *logos* = discourse) is the science of life. It investigates all questions pertaining to living things. Physics

FIG. 1.—Crystals of ice on a window-pane. In the crystal inanimate matter manifests itself in its nearest approach to the characteristics of living matter.

and chemistry deal primarily with matter and energy without regard to life. It is, however, impossible to study any one of the sciences properly apart from all the others.

The term "matter" includes everything which has weight and occupies space. We may divide matter into two classes,—the *living* and the *nonliving*. We can all recognize that a stone is inert and that an oak tree is alive, but the status of a crystal of copper sulphate is not so easily established by the untrained.

We shall now consider some of the main points of difference between the living and the nonliving.

1. Plants and animals grow by taking in food substances and changing their chemical composition before adding them to themselves. Minerals do not do this. A crystal of copper sulphate may

FIG. 2.—A humming bird's nest. It is in connection with the phenomena of reproduction that life reaches its highest and most essential expression.

"grow," but the material added to it is always more copper sulphate, and its chemical composition is not changed when it is combined with the crystal.

2. Plants and animals have the power to reproduce their own kind,—usually by spores, seeds, or eggs. Minerals have no methods of reproduction.

3. Plants and animals are more complex in their physical and chemical make-up than minerals. In other words, plants and animals are highly *organized*, being composed of definite parts or organs; each organ having some special work to do for the good of the whole living thing, or *organism*.

4. Some forms of mineral matter may exist for an indefinite

FIG. 3.—The General Sherman Tree in the Sequoia National Park. This tree is thought to be the largest and oldest thing in existence, but it too must die some time. (*Photo by Pillsbury.*)

period; but all living individuals, with the possible exception of some of the simplest forms (see Study 25), must die.

5. All living things are *irritable,—i.e.*, they are capable for responding to an influence. A sunflower bends its top during the day so as to receive the maximum amount of sunlight. A frog jumps into the water when it is frightened. The influence which prompts the activity is called a *stimulus* and the resulting action is called a *response*. Minerals are not irritable as living things are, although the action of light on a photographic plate, for instance, is suggestive of this condition.

All living things are composed of matter and liberate energy within their bodies from their food substances for the maintainance of their life activities. The chemists tell us that there are about ninety different, elementary kinds of matter. These *elements* combine in various ways to form all of the different kinds of material in the universe. Of these ninety elements only twelve are found extensively in the bodies of plants and animals. They are listed, together with their chemical symbols, in the table below.

1. Oxygen	O	7. Calcium	Ca
2. Carbon	C	8. Potassium	K
3. Hydrogen	H	9. Sodium	Na
4. Nitrogen	N	10. Iron	Fe
5. Phosphorus	P	11. Silicon	Si
6. Sulphur	S	12. Chlorine	Cl

The smallest unit particle of an element is known as an *atom* and the various unit combinations of these atoms are known as *molecules*. For example,—12 atoms of carbon, 22 atoms of hydrogen, and 11 atoms of oxygen may combine to form one molecule of sugar. It is abbreviated thus: $C_{12}H_{22}O_{11}$. The abbreviation is known as a *chemical formula*.

Carbohydrates.—Sugar is an example of a class of chemical substances called *carbohydrates*. They are found in the bodies of plants and animals. Some other examples are *starch* and *cellulose* which make up most of the solid matter in the bodies of plants, *glycogen* which is found in the bodies of animals, and *dextrin* which is used as mucilage. These substances contain twice as many atoms of hydrogen as they do of oxygen, and since this is the ratio of

hydrogen to oxygen in water (H_2O) they are called *carbohydrates* (*carbo* = carbon and *hydrate* = water).

The organic fats and oils constitute another group of substances found in plants and animals. They are entirely different chemically from the mineral oils, such as the petroleum products, although they resemble them physically. Olive oil, castor oil, lard, and tallow are examples. Fats are composed of carbon, hydrogen, and oxygen.

Proteins are complex substances found in all plants and animals. They are composed of carbon, hydrogen, oxygen, nitrogen, and sulphur (C, H, O, N, S), and may also contain phosphorus and iron. The white of an egg is nearly pure protein. Other examples are muscle tissue, brain and nervous tissue, and the outer layer of grains. Bran is very rich in protein.

Out of these three classes of food substances, together with some mineral matter and water, the bodies of plants and animals are built up. The fats and carbohydrates are deposited in the tissues of living things as food or structural material and are not, to speak correctly, alive. The proteins are the principal constituents of the living part of the organism. This living substance is called *protoplasm*. Its nature is not fully understood.

Biology, *the science of life*, should be an interesting part of the education of every high school boy or girl. What is more interesting than life itself! But biology has long ceased to be a pure science of mere academic interest. It is inseparably linked with the agricultural, economic, civic, and religious progress of the country. The educator is better able to solve the problems of education when he comes to know that man is a rising animal and not a fallen angel. The farmer is able to constantly improve his live stock and plant-crops when he applies the known principles of breeding. Disease has been greatly reduced by the application of the principles of sanitation. Biology supports the movement for fresh air, parks, playgrounds, athletics, and temperance. Knowing that degenerate individuals breed degenerates, the eugenics movement has been inaugurated for the improvement of the human race. We are able to look upon the criminal, the pauper, and the feeble minded with more sympathy when we realize that these unfortunates are what they are because of heredity and environment.

The three great elementary industries of fishing, lumbering, and agriculture are biological. Of the work of the United States Government in propagating and conserving the fish and forests we shall have something to say later on.

Biology does not neglect the aesthetic nature of man. If the wild life of this country is to be preserved for the future generations to enjoy, it must be protected. The passenger pigeon is extinct. The turkey, swan, and sand hill crane, as wild animals, are very rare and may not survive this generation. Many of our most beautiful

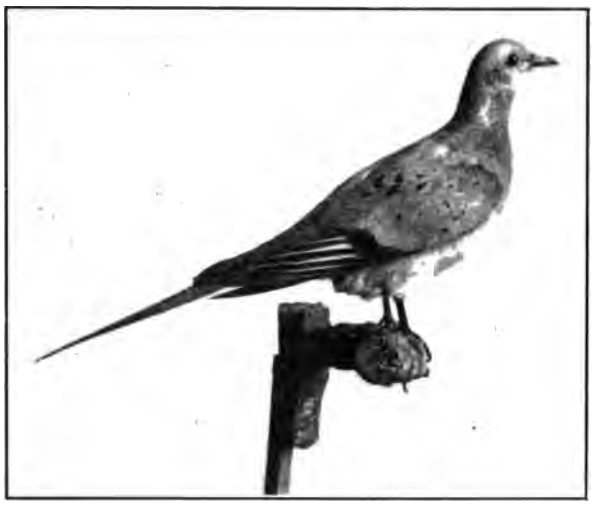

FIG. 4.—The extinct passenger pigeon. This is a photograph of one of the last specimens killed in Wisconsin.

wild flowers have been exterminated in the vicinity of cities. Forest dwelling animals have disappeared with the destruction of the forest. Much has been done by establishing game preserves and enforcing game laws, but the safety of our wild life can not be assured without an education which will stimulate an appreciation for it and a general knowledge of its value.

Finally, a high school course in biology should be more than a study of plants for one half year and animals for the other. The year's work should be a unit, and the emphasis should be upon *life*.

Students of the *Science of Life* should not hesitate to investigate any activity of life, therefore the study should be as broad as life itself.

Suggestion.—It will be profitable to have the students prepare topics on such subjects as athletics, parks, feeblemindedness, wild life, etc. to be given later in the course.

Laboratory Projects.—Make a hot, saturated solution of copper sulphate, ammonium nitrate, or sugar and let it stand until crystals form. Observe them from time to time as they "grow." If the liquid is placed in a tall vessel, and a string is suspended in it, the crystals will collect on the string.

Plant some seeds and observe their germination.

Design an experiment to illustrate the response of plants to sunlight, or the irritability of one of the lower animals.

Secure samples of the twelve elements mentioned in this study, and pass them around the class. It may be interesting to observe some of their simpler compounds also.

Secure various samples of carbohydrates, fats, and proteins and pass them around the class. Compare them with elements and with minerals.

Suggestion.—Let the students do as much of the laboratory and project work as possible. Assign the work to various individuals and groups some days before the matter is to be taken up in class. As a general rule, the presentation of the laboratory and assigned work should precede the reading of the text; but not in all cases.

References.—The following carefully selected list of references is given in the hope that teachers will try to secure as many of the books as possible. Get a few each year and have a place in the biological laboratory where they may be kept. They will not be so readily accessible if they are in the general library. It is more convenient for students to work up their reports in the laboratory. There should be definite periods in the day when this work may be done under the supervision of the teacher. Can a committee of students be appointed each year to take charge of the arrangement and cataloging of the books in the "Biological Laboratory Library"?

Publications of the U. S. Department of Agriculture.
Publications of the U. S. Bureau of Entomology.
Publications of the U. S. Fish Commission.
Publications of the various states' departments of agriculture.
The National Geographic Magazine.
The Journal of Heredity.
Animal Communities in Temperate America, Shelford, University of Chicago Press.
Applied Economic Botany, Cook, J. B. Lippincott Co.
Anatomy and Physiology, Bundy, P. Blakiston's Son & Co.
Animals Before Man, Lucas, D. Appleton & Co.

Animals of the Past, Lucas, McClure Phillips & Co.
Biology of the Frog, Holmes, Macmillan Co.
Being Well Born, Guyer, Bobbs-Merrill Co.
Botany of Crop Plants, Robbins, P. Blakiston's Son & Co.
Bacteriology and Animal Parisitology, Stitt, P. Blakiston's Son & Co.
Blossom Hosts and Insect Guests, Gibson, Newson & Co.
Book of the Home Garden, Fullerton, D. Appleton & Co.
College Zoology, Hegner, Macmillan Co.
Comparative Anatomy of Vertebrates, Kingsley, P. Blakiston's Son & Co.
Common Spiders, Emerton, Ginn & Co.
Development of the Frog's Egg, Morgan, Macmillan Co.
Development of the Human Body, McMurrich, P. Blakiston's Son & Co.
Domesticated Animals and Plants, Davenport, Ginn and Co.
Economic Entomology, Lochhead, P. Blakiston's Son & Co.
Embryology of the Chick, Patten, P. Blakiston's Son & Co.
Entomology, Folsom, P. Blakiston's Son & Co.
Evolution and Animal Life, Jordan and Kellogg, D. Appleton & Co.
Evolution of Sex in Plants, Coulter, University of Chicago Press.
Experiments with Plants, Osterhout, Macmillan Co.
Farm Friends and Farm Foes, Weed, D. C. Heath & Co.
Familiar Trees, Mathews, D. Appleton & Co.
Field Zoology, Crary, P. Blakiston's Son & Co.
Fundamentals of Botany, Gager, P.Blakiston's Son & Co.
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General Biology, Abbott, Macmillan Co.
General Zoology, Pearse, Henry Holt & Co.
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How to Know the Mosses, Dunham, Houghton Mifflin Co.
In Beaver World, Mills, Houghton Mifflin Co.
Life's Beginnings, Hall, Association Press, New York.
Life of Inland Waters, Needham and Lloyd, Comstock Pub. Co.
Life of the Spider, Fabre, Dodd, Mead & Co.
Manual of the Botany of the Northern United States, Grey, American Book Co.
Mendelism, Punnett, Macmillan Co.
Mendel's Principles of Heredity, Bateson, G. P. Putnam's Sons.
Michigan Trees, Otis, University of Michigan Press.
Microbiology, Marshall, P. Blakiston's Son & Co.

Mighty Animals, Mix, American Book Co.
Mosquito Life, Mitchell, G. P. Putnam's Sons.
Mushrooms, Hard, Ohio Library Co., Columbus, O.
Nature Sketches in Temperate America, Hancock, A. C. McClurg & Co.
New Nature Library, Doubleday Page & Co.
Our Native Trees, Emerson & Weed, J. B. Lippincott Co.
Plant Anatomy, Stevens, P. Blakiston's Son & Co.
Principles of Animal Biology, Shull, McGraw-Hill Book Co.
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2. ENVIRONMENT

How is life related to the factors of its environment?

In biology the word *environment* is used to signify the total conditions upon which the life of a plant or an animal depends. The special study of the relation of life to its environment is called *ecology*. Its literal meaning is *the study of homes*.

In this study we shall try to classify under seven headings the most important elements which make up the environment. They are: 1. temperature, 2. water, 3. light, 4. air, 5. soil, 6. food, 7. shelter.

Temperature.—We have learned in geography that the earth may be divided into five zones or belts of varying temperature,—the two Arctic Zones, the two Temperate Zones, and the Torrid Zone. It is obvious that the temperature of a plant or an animal must be above that at which the fluids in it freeze or it can not live.

In the Torrid Zone there is no winter and the plants grow continually. There is no need of protection from cold. Tempera-

ture conditions here are the most favorable, and life is very abundant.

In the Temperate Zones there is a cold winter and a warm summer. This is especially true of the North Temperate Zone where the large land masses give great extremes of temperature. Life here must be able to withstand great seasonal extremes of heat and cold. The summer is the season of growth and reproduction, and the winter is the season of rest and retreat.

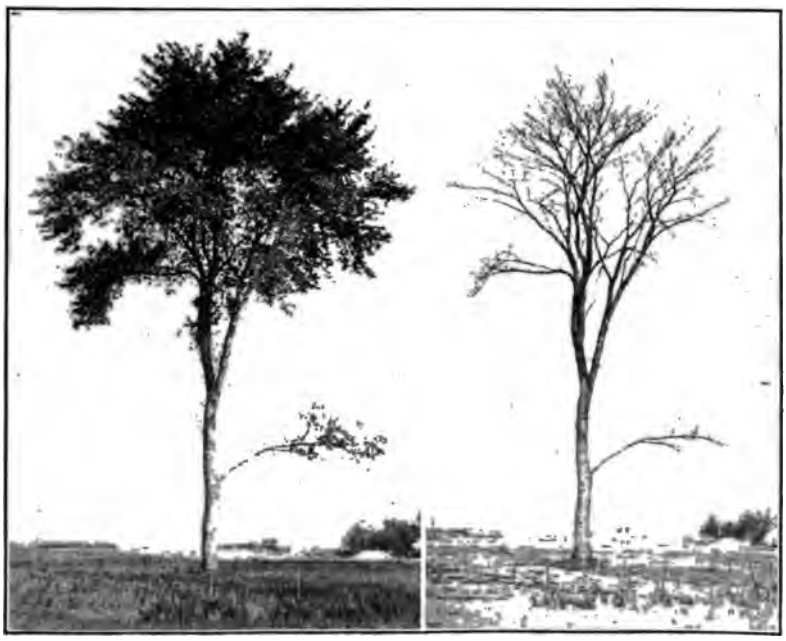


FIG. 5.—An elm tree in summer and in winter. Plants which live in the temperate zones must have special methods of surviving the cold winters.

Many of the birds migrate to a warmer climate in winter. Frogs, snakes, and turtles bury themselves in the earth or the mud of ponds. Woodchucks and chipmunks sleep in their dens. This winter rest is known as *hibernation*. Name as many animals as you can which hibernate. Many of the trees shed their leaves and cease to grow.

Such trees are said to be *deciduous*. Name some trees which are and some which are not deciduous. Many plants die entirely and preserve the race through the winter by means of their seeds which do not freeze but grow the next summer.

In the Arctic Zones it is cold all the time, but in the southern part of the North Arctic Zone there is a short time in the summer when plants may grow. These plants must be able to blossom and ripen their seeds very quickly. The land animals are covered with a heavy coat of fur and either hibernate in winter or wander over extensive areas in search of food.

Altitude is another important factor in determining temperature. The tops of mountain ranges are cold, and life conditions here resemble those in arctic regions in many respects.

Water.—The bodies of plants and animals are composed largely of water. Life can not exist without it. Mention some of the ways in which water is of importance to animals.

Water exists in varying quantities in the air, and the amount that the air can hold depends upon the temperature. Warm air can contain more water vapor than cold air. When air containing water vapor is chilled, its ability to hold vapor is reduced. If more water vapor is present than can be held, it falls in the form of rain or snow.

Regions where the rainfall is not sufficient for a vigorous growth of vegetation are called *deserts*. The plants here store up food and moisture during the rainy season and have few or no leaves. The plants of the genus *Yucca*, however, have thick, juicy leaves in which food is stored. These plants are "stemless" except when they are in blossom. When leaves are absent the stems are green and function as leaves. Food is stored in either the root, stem, or leaf. The animals generally wander extensively in search of food and require very little water. Name some desert plants and animals and discuss their special adaptations for desert life.

Rain water either runs off from the surface of the earth to form streams, sinks into the ground to emerge again in the form of springs, or evaporates and returns to the air. A large part of it enters rivers and flows to the sea. Ocean water differs from that of most lakes in that it contains salt. The presence of salt has a great effect on

w forms of plants or animals are able to inhabit both
ater.

ieve that the first forms of life lived in the seas, and
any of the simplest and most ancient forms are found
nditions of life in the oceans are believed to have
le throughout the centuries, and this has permitted
forms to remain undisturbed.

Fig. [illegible] Fig. [illegible]

[illegible] crinoid from Tennessee. This creature lived in the sea
[illegible] what is now the State of Tennessee. From Troost's
[illegible] U. S. National Museum Bulletin [illegible]
[illegible] crinoid. Note the great [illegible] between his specimen
[illegible] Tennessee. The [illegible] have probably changed
[illegible] the ages [illegible]

[illegible] all see in Study [illegible] how light is used by plants in
[illegible] of their food and understand that without light
[illegible] green plants [illegible] Since the animals are dependent
[illegible] their food [illegible] Almost every

one has noticed how the leaves of many plants adjust themselves so as to receive a maximum of sunlight. This turning of leaves toward light is known as *phototropism* (*Gr. phos* = light + *trope* = a turning). It is a very common phenomenon among plants which thrive in sunlight and shows the importance of sunlight to plants.

FIG. 8.—Two views of a begonia plant showing its response to light.

Animals are dependent upon light largely through their sense of sight. Animals which take up a cave or underground life usually loose the use of their eyes and have other structures such as feelers very highly developed.

Air.—The composition of the air is shown in the table on p. 14.

Of these five gases oxygen, water vapor, and carbon dioxide are essential to the life of the earth. It is common knowledge that oxygen is essential for respiration in animals, but it is not so well known that plants respire also. Respiration will be discussed in Study 13 and Study 17.

The air takes up water vapor from the soil, from plants and animals, and from the surface of lakes and oceans and distributes it

Composition of the Air

Name of gas	Per cent of volume
Nitrogen	76.95
Oxygen	20.61
Argon	1.00
Carbon dioxide (average)	0.03
Water vapor (average)	1.40
Air	100.00

over the face of the earth. Thus the rainfall of a place is largely dependent upon the prevailing wind direction.

Although there is only a small amount of carbon dioxide in the air, it is very important because out of it plants make a great part of their food. This process will be discussed in Study 13. The carbon dioxide of the air is of little direct importance to animals.

Soil.—Soil is of importance to plants in that they are anchored to it by their roots and that they get their water and mineral food from it. It is well known that a vigorous plant growth does not take place on a poor soil. Animals are not apparently so dependent upon soil conditions as are plants, because their dependence is indirect. Soils will be more fully discussed in Study 8.

Food.—The food supply of plants is comparatively simple. They absorb simple substances from the soil and air, and in the presence of sunlight manufacture food from them. Thus plants build up food. Animals take in food that is already built up and oxidize it in their bodies and thus reduce it to simple substances again. This production of food by plants, and its destruction by animals, is known as the *food cycle*.

There is a great struggle in life for food. This is not always easily apparent, but it will be shown later on that the abundance of any plant or animal in a given locality is determined largely by the food supply.

Shelter.—Under this term ecologists group all those characters of plants and animals which enable them to escape death from enemies

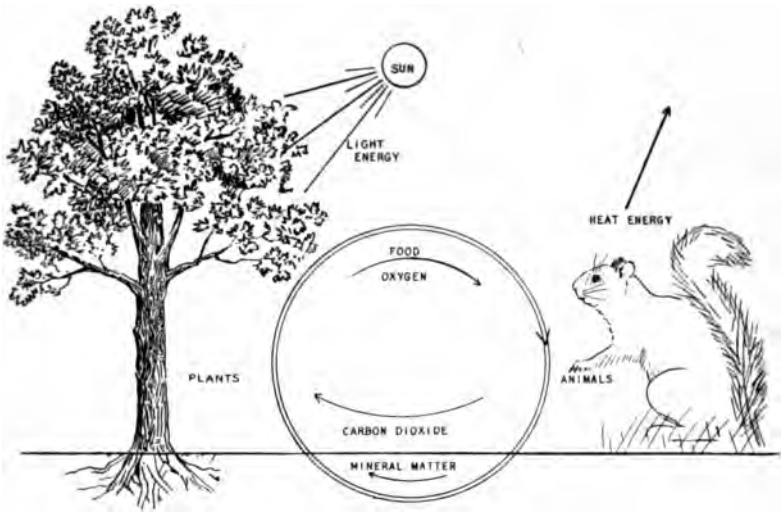


FIG. 9.—Diagram of the food cycle.

FIG. 10.—A spray of poison ivy, an example of a plant which is protected by its poison juice. Learn to know and avoid this plant on your field trips. Its leaf-stem bears three leaflets; other ivies have five. Is it ever eaten by insects? How can you find out?

or an unfavorable environment. The cactus has its thorns, the poison ivy its poisonous juice, the jimson weed its bad odor, and the fennel its bitter taste. The toad is colored to match its surroundings. The crayfish has its pinchers, the bee its sting, and the stag his horns. The rabbit is fleet of foot; the chipmunk retreats to its hole in the ground. The methods of seeking protection are various but they all tend to accomplish the same object which is the preservation of the individual and the race.

In this study we have outlined the main environmental factors which combine in different ways in different localities to make up the conditions in which plants and animals live. We shall find later on that life is always fitted or *adapted* to its environment. The cactus can not live in swamps nor can the water lily live in deserts, but each is fitted to live successfully in the place where it is found.

Field Trip.—If the vicinity of the school affords them, some of the features mentioned in this study should be visited. Make a systematic study, with definite assignments to various groups. Make the assignments before starting on the trip, and report from notes in class the day following. Is it necessary for all of the class to go to the same place? Can a group work successfully without the presence of the instructor?

Reports.—Let each student select a plant or animal and report on its method, or methods, of securing shelter.

3. ADAPTATION AND THE PRINCIPLES OF CLASSIFICATION

How is life adapted to its environment?

There are many different kinds of places on this earth where plants and animals may live. Even in a restricted environment like a pond living things may be found at the bottom, or at the surface of the water; in the mud near the shore, or out in the deeper water; on plants under water, or on plants above water; swimming free, or attached; and in other situations. In the millions of years that plants and animals have lived on the earth they have gradually adapted themselves to live in various situations, in various relations to other living things. As conditions have changed, life forms have been compelled to change or disappear. The number of kinds of plants and animals living on the earth today is small compared to the number of those that have lived and perished. Within the recol-

›n of man the mammoth, saber-toothed tiger, dodo, passenger ›n, and many others have become extinct.

ıe ability of life to change its structure and habits to conform to .nging environment is known as *adaptation*, and this has resulted .e multitude of plant and animal forms that inhabit the earth y. We will say more about this matter later on in the course. 520,000 different kinds of animals and nearly as many different ; of plants are known. There are also many kinds that have ıs yet been named and described in scientific literature.

FIG. 11.—A fossil cup coral. A type of life which is now extinct.

.ch plant and animal known to science is named in accordance a plan devised by Linnæus (1707–1778), a Swedish botanist. system has been revised from time to time but its essential iples remain unchanged.

ıssification is based on *relationship*,—*e.g.*, animals or plants which losely related are placed together in groups. The relationship ınts and animals is determined by a knowledge of their *structure*, *yology*, *history*, *geographical distribution*, *habits*, and *ability to cross-* with related forms.

The structure of an animal refers to its various parts,—*e.g.*, feet, teeth, bones, etc. The teeth of the lion and tiger are very similar,

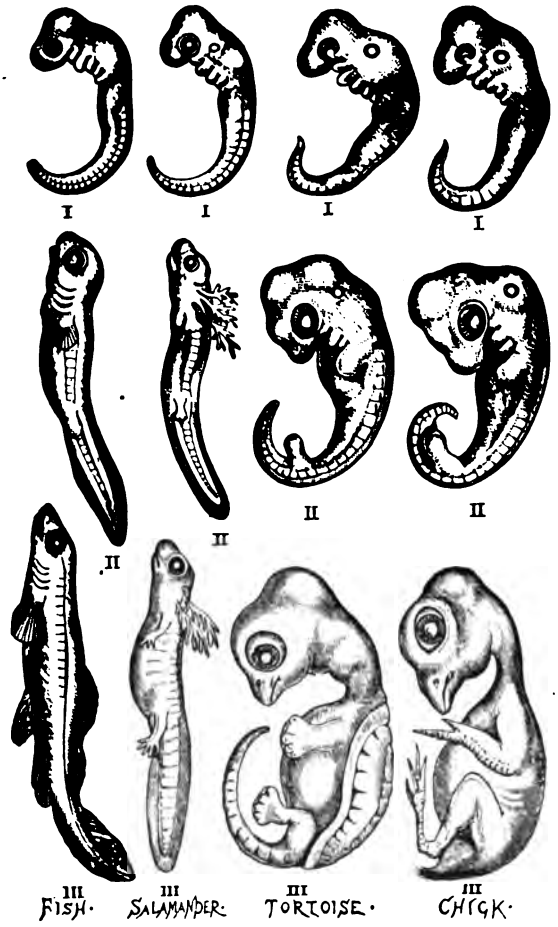


FIG. 12.—Three stages in the development of the fish, salamander, tortoise, and chick to show their similarity. (*From McFarland, after Hackel.*)

but those of a horse are very different; thus, animals which are closely related have similar teeth.

The embryology of an animal refers to its development from the

egg to the adult. All vertebrate animals at a certain stage of their development have gill-bars. This shows their relationship and indicates that they at one time lived in the water and breathed as the fish does now. See Fig. 12.

The history of a species refers to its development from its remote ancestors to its present condition. Animals which are closely related have pursued a similar historical development, and their embryological stages are similar. This fact was first noted by von Baer, a Russo-German naturalist, born in 1792, and is known as *von Baer's Law.*

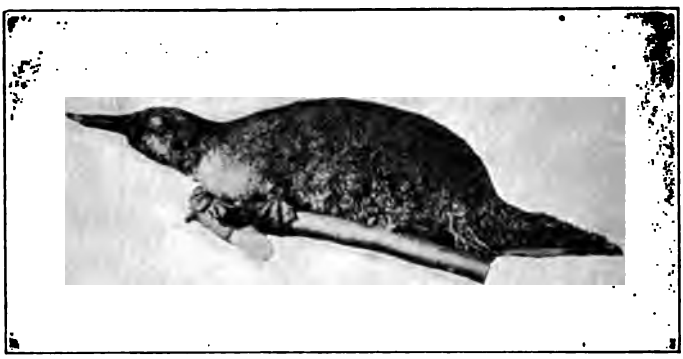


FIG. 13.—The duckbill of Australia. This animal has a skeleton which resembles that of a reptile in many ways. It lives in the water like a muskrat, and lays eggs like a reptile. It is found only in Australia. (*From Folsom.*)

The fact that the historical development of the species is summed up or repeated in the embryological development of the individual is known as the *recapitulation theory.* The history is never perfectly repeated, and there are many short cuts and slight omissions.

The most definite information concerning the history of plants and animals has been gained from an examination of the fossils which are found in rocks. The study of fossils is known as *paleontology* which means the science of ancient things.

Geographical Distribution.—The native mammals of Australia are all members of the orders *Monotremata* and *Marsupialia.* This is believed to be due to the fact that the continent has been separated from the other land masses for a long time, and these were the only

types of mammals living on the earth when the separation took place. The monotremes (duckbills) are found nowhere else, and the marsupials (kangaroos, etc.) are represented elsewhere by one group, the opossums of North and South America. Many animals from other continents thrive in Australia now that man has introduced them.

FIG. 14.—The opossum of North America. This animal carries its young in a pouch like the kangaroo.

Habits.—Animals which are closely related have similar habits. Lions, tigers, panthers, leopards, and the domestic cat are closely related. They all catch prey in a similar way,—by stealth; but not in exactly the same way. Each form behaves according to the general habits of the group but has its own characteristics,—*e.g.* panthers and leopards commonly climb trees, but lions do not.

Cross-breeding.—The test of cross-breeding is applied to forms that are closely related. The lion and the tiger are more closely related than the domestic cat and the tiger, for the lion and the tiger will cross-breed, but the tiger and the domestic cat can not. The offspring of such cross-breeding is known as a *hybrid*. If the parents are not closely related the offspring will not breed and so the new type can not perpetuate itself. Dogs and wolves often cross-breed. In this case the young are able to breed, and the hybrids may be

FIG. 15.—Squashes. Produced by hybridization from wild ancestors. Do you know the name of each kind represented in the illustration?

perpetuated. The mule is a cross between the horse and the donkey, but mules never bring forth colts. It is believed that the wolf and the dog are very closely related, and that the donkey and horse are not so closely related. The crossing of plants and the production of hybrids is the chief method by which the multitude of domestic plant forms have been produced from their wild ancestors.

Taxonomy is the classification of plants and animals. When we find a large number if individuals so nearly alike that they are practically identical, they are put in one group called a *species*. It is the unit of classification. All lions belong to the species *leo*, all tigers to the species *bengalis*, all domestic cats to the species

domestica. While all domestic cats are very much alike, they, however, are of certain types. Some are black, some white, some long haired, some short haired, etc. These are grouped in subdivisions called *races* or *varieties.* The varieties of a species are usually able to inter-breed readily.

Species which are closely related, such as the cat, lion, tiger, and puma fall naturally into a larger group called a *genus* (pl. *genera*). A genus is composed of closely related species. When an animal is named it always bears two names—the *generic* and *specific.* The generic name is always spelled with a capital letter and the specific with a small letter even if it is derived from a proper noun. The scientific name for the lion is *Felis leo;* the tiger is *Felis bengalis;* the Canadian lynx is *Lynx canadensis.*

Genera fall naturally into larger groups called *families.* All cat-like animals belong to the cat family, bear-like animals to the bear family, and wolf-like animals to the wolf family which includes the dogs.

Families are arranged in *orders.* As we arrive at the larger groups the system becomes less natural and more artificial because relationships can not always be determined accuraely. All flesh-eating animals—cats, bears, dogs, seals, etc. are placed in the order *Carnivora.*

Orders are arranged in *classes.* Fur-bearing animals possess mammary glands for nursing their young. They belong to the class *Mammalia.*

Classes are arranged in *phyla* (Sing. *phylum*). All animals having a backbone, such as fishes, frogs, lizards, birds, and mammals are put in the sub-phylum *Vertebrata* which is in the phylum *Chordata.* In this case a sub-phylum is made. We may have *sub* or *super* phyla, classes, orders, and genera.

The phyla are the largest divisions of the plant and animal *kingdoms.* Thus we have the following systematic arrangement: *variety, species, genus, family, order, class, phylum, kingdom.*

The scientist who first describes a plant or animal has the right to name it, and it must be known by that name forever afterward. The names all have Latin endings. This is not necessary but was started by Linnæus and has certain conveniences which cause it to be continued.

4. CLASSIFICATION OF THE PLANT AND ANIMAL KINGDOMS

How and why are plants and animals classified?

In this study we will outline the phyla and classes of the plant and animal kingdoms. Some of the less important groups will be left out or condensed for the sake of brevity. The new and unfamiliar terms will be explained in the text later on. All of the groups should not be learned at once, but they should be studied in connection with the illustrations, and the table should be constantly referred to throughout the course. When an animal or plant is studied it should be referred, in the mind of the student, to its proper position in the scheme of classification. Subject to the limitations of time and opportunity, observation and laboratory work should be done on the type forms.

THE PLANT KINGDOM

PHYLUM I. THALLOPHYTA: plants without true roots, stems, leaves or flowers. Reproduce by spores.

SUB-PHYLUM 1. ALGÆ: plants possessing chlorophyll.

SUB-PHYLUM 2. FUNGI: plants without chlorophyll.

This is the simplest group of plants. They live largely in the water and have no fibrovascular tissue, hence, each cell is largely independent of the others in food getting but not entirely so in all cases. *Pond scums* and *green slime* belong to the algæ. *Bacteria*, *yeasts*, *molds*, and *mushrooms* belong to the fungi.

PHYLUM II. BRYOPHYTA: green plants without true roots, stems, leaves or flowers; reproducing by spores with alternation of generations. The *liverworts* and *mosses* constitute the two classes.

PHYLUM III. PTERIDOPHYTA: green plants having roots, stems and leaves but no flowers; reproducing by spores with alternation of generations. The *ferns*, *horse-tails*, and *club mosses* constitute the three classes.

PHYLUM IV. SPERMATOPHYTA: green plants having roots, stems, leaves, and flowers or cones. Reproducing by spores (pollen and ovules) with alternation of generations and seed.

SUB-PHYLUM 1. GYMNOSPERMÆ: cone bearing plants, usually evergreens such as *pine*, *spruce*, *hemlock*, cedar, cypress.

FIG. 16.—Representatives of four groups of spore producing plants. *A*, a red alga; *B*, a mushroom belonging to the fungi; *C*, moss plants; *D*, a fern plant.

FIG. 17.—Representatives of four groups of seed producing plants. *A*, a cedar tree; *B*, a palm; *C*, tulips (Monocotyledon); *D*, a cosmos (Dicotyledon).

SUB-PHYLUM 2. ANGIOSPERMÆ: flowering plants. They are divided into two classes,—MONOCOTYLEDONS and DICOTYLEDONS. The monocotyledons have one seed leaf, an endogenous stem, parallel veined leaves, and flower parts arranged in threes. The dicotyledons have two seed leaves, an exogenous stem, net veined leaves, and flower parts arranged in fours or fives.

THE ANIMAL KINGDOM

PHYLUM I. PROTOZOA: unicellular animals.

Class 1. RHIZOPODA: no definite cell wall, form pseudopodia. Examples: *Ameba, Difflugia, Arcella, Actinosphaerium.*

Class 2. MASTIGOPHORA: possess flagella and often chlorophyll. Examples: *Mastigamœba, Euglena* (*Pandorina* and *Volvox* are usually classed as plants but should be mentioned here also).

Class 3. INFUSORIA: possess cilia or tentacles. Examples: *Paramecium, Stentor, Stylonchia, Vorticella.*

Class 4. SPOROZOA: parasitic forms, reproducing by swarm spores. Examples: *Monocystis, Plasmodium.*

PHYLUM II. PORIFERA: *sponges.*

PHYLUM III. CŒLENTERATA: radiate animals without anus or body cavity. Examples: *hydra, jellyfish, corals, anemones.*

PHYLUM IV. ECHINODERMATA: radiate animals with complete alimentary canal and body cavity. There are five classes,—*sea-lilies, sea-urchins, brittle stars, starfish, sea-cucumbers.*

PHYLUM V. PLATYHELMINTHES: unsegmented flat worms. There are three classes,—*planarians, tapeworms, flukes.* The planarians are free living; the others are parasitic.

PHYLUM VI. NEMATHELMINTHES: unsegmented round worms. Examples: *intestinal worms, vinegar eels, trichina.*

PHYLUM VII. ANNULATA: segmented worms. Examples: *earthworm, tube-worm, leech.*

PHYLUM VIII. MOLLUSCA: unsegmented, soft bodied animals with an internal or external shell.

Class 1. GASTEROPODA: univalves,—*snails* and *slugs.*

Class 2. PELECYPODA: bivalves,—*clams* and *oysters.*

Class 3. AMPHINEURA: many-valved,—*chitons.*

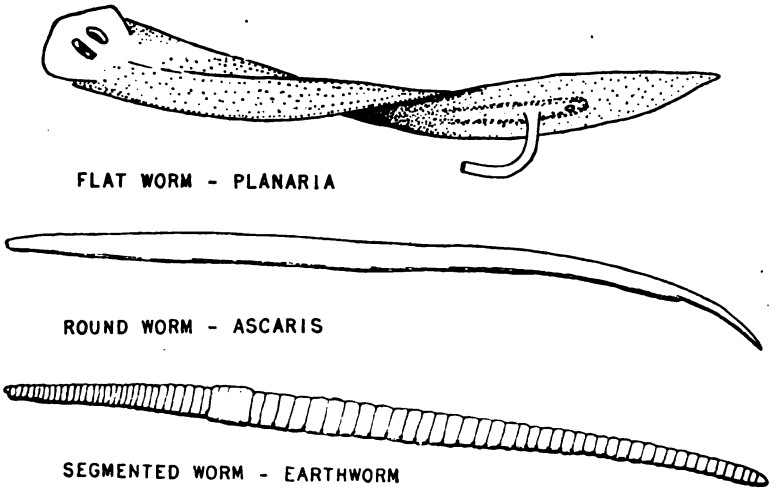


FIG. 18.—Three types of worms.

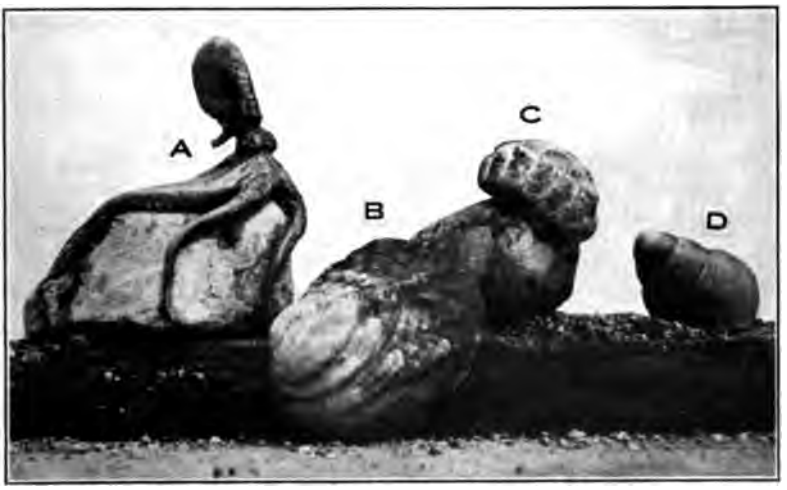


FIG. 19.—Four types of molluscs. ***A***, **a cephalopod (octopus);** ***B***, **a pelecypod or lamellibranch (clam);** ***C***, **an amphineuron (chiton);** ***D***, **a gastropod (snail).**

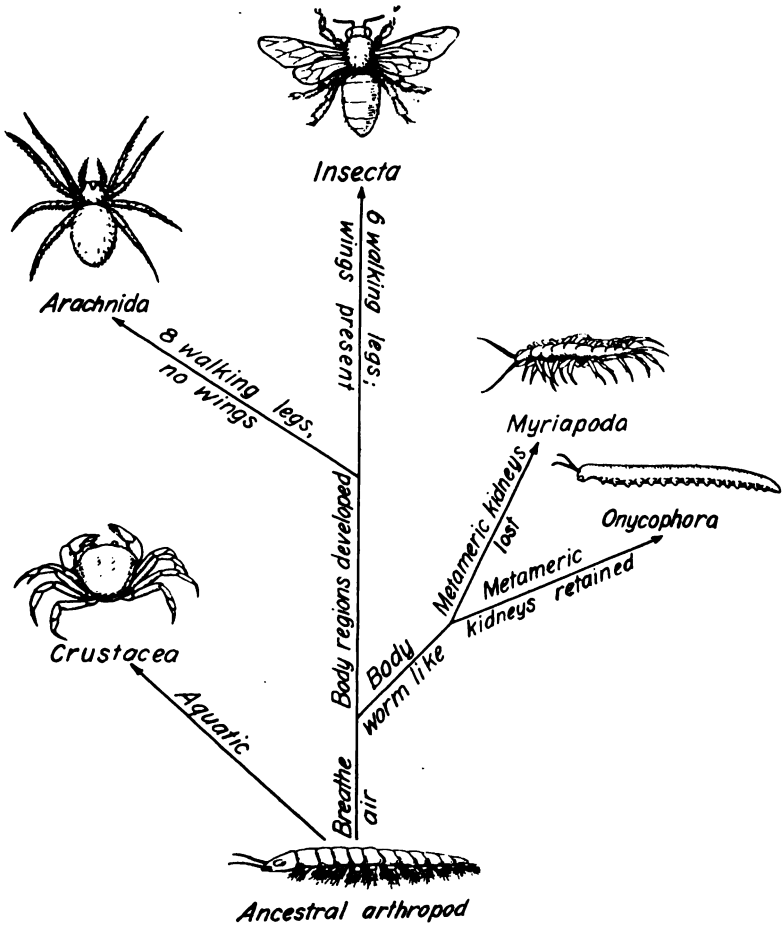


FIG. 20.—A scheme to show how the five classes of arthropods have developed from their common ancestor. (*After Pearse, General Zoology; Henry Holt & Co.*)

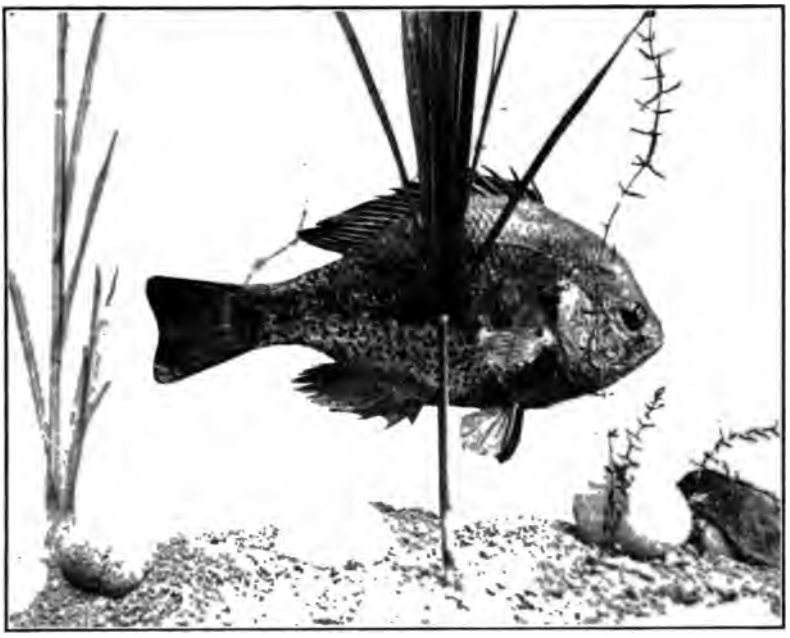


FIG. 21.—A bluegill, one of the bony fishes.

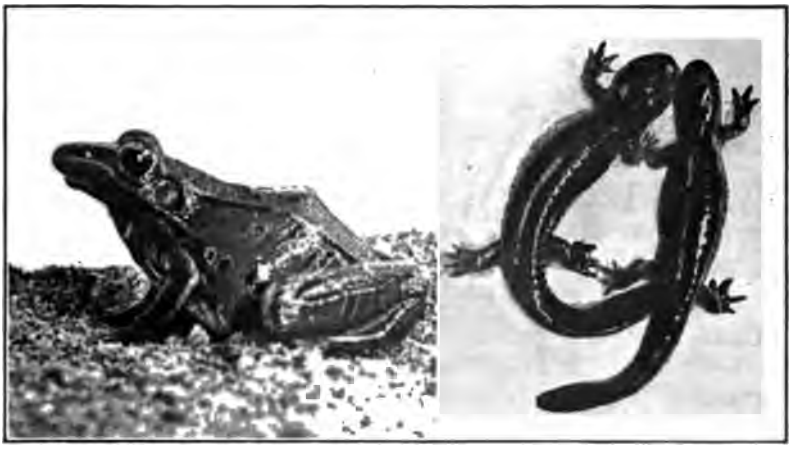


FIG. 22.—Amphibians—The leopard frog, and two tiger salamanders.

Class 4. CEPHALOPODA: with many tentacles and eyes similar to those of the vertebrates. Examples: *squid*, *cuttle-fish*, *octopus*, *nautilus*.

PHYLUM IX. ARTHROPODA: animals with jointed legs, an external skeleton, and ventral nervous system.

Class 1. ONYCHOPHORA: worm-like, breathe with tracheæ. Example: *peripatus*.

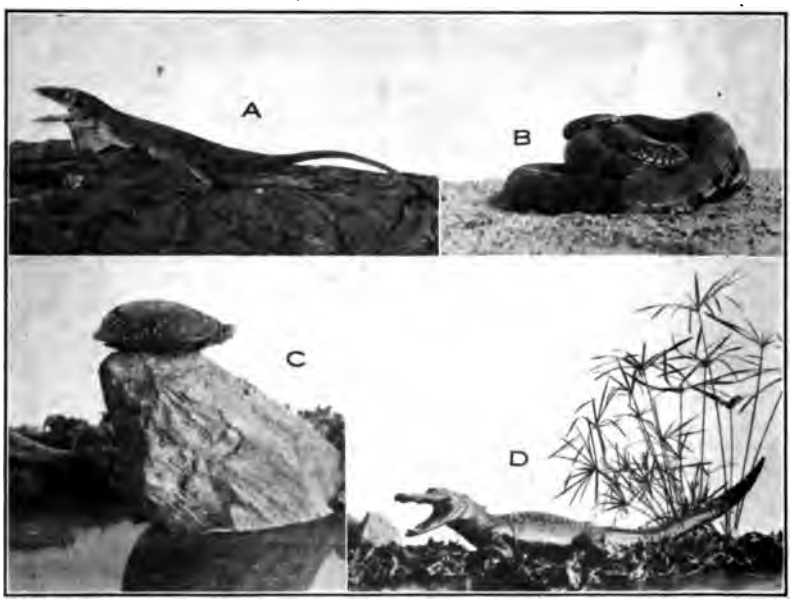


FIG. 23.—Typical reptiles representing four classes—*A*, the chameleon in its terrifying attitude, a member of the lizard group; *B*, the water snake in an attitude of fear; *C*, the spotted turtle at rest; *D*, an alligator in great anger and excitement. The picture of the alligator is from a mounted specimen; the others are from life.

Class 2. MYRIOPODA: long bodies, many legs, breathe with tracheæ. Examples: *centipeds* and *millipedes*.

Class 3. CRUSTACEA: breathe with gills or with no special respiratory structures. Examples: *pill-bugs*, *barnacles*, *crayfish*, *crabs*.

FIG. 24.—The brown thrasher, a representative of the birds.

FIG. 25.—The raccoon, a representative of the mammals. This specimen is shown balancing himself with his tail as he is coming down to the water.

Class 4. ARACHNIDA: eight legs, breathe with lung-books. Examples: *spiders, scorpions, ticks, mites, horseshoe crab.*

Class 5. INSECTA: six legs, breathe with tracheæ. Examples: *insects.*

PHYLUM X. CHORDATA: animals with a notochord or vertebral column.

SUB-PHYLUM—VERTEBRATA: animals with a vertebral column, dorsal nervous system and gills in embryo or adult.

Class 1. PISCES: breathe with gills, body covered with mucus, often with scales, cold blooded. Example: *fish.*

Class 2. AMPHIBIA: breathe with gills, lungs, or through the skin; body covered with mucus or dry, never with scales; cold blooded; no ribs. Examples: *newts, salamanders, frogs, toads.*

Class 3. REPTILIA: breathe with lungs, body covered with scales, cold blooded. Examples: *lizards, alligators, snakes, turtles.*

Class 4. AVES: breathe with lungs, body covered with feathers, warm blooded. Example: *birds.*

Class 5. MAMMALIA: breathe with lungs, body covered with hair, warm blooded, possess mammary glands. Example: *mammals.*

Suggestion.—It may be profitable to go to a botanical garden or a museum to observe examples of the phyla and classes mentioned in this study.

5. THE LIFE OF THE GOLDENROD

How has the goldenrod solved the problems of plant life?

Field Trips.—We are now ready to go out into the fields and study a typical plant and see how it lives. In the autumn the untilled fields invite us to go forth and admire the rich, yellow flower clusters of the goldenrod. It is found everywhere in open fields of waste land.

Like most other plants the goldenrod is composed of four different kinds of structures, each having its special work to do for the good of the whole plant. These structures are the root, the stem, the leaves, and the flowers. We will take them up in their turn and study them.

The roots of the goldenrod are numerous, small in diameter, all of about the same size, and spread in all directions. This type of root is called a *fibrous root.*

If we try to pull a plant out of the ground we will find that the roots hold it firmly and that it is necessary to break them off before the plant comes out. This is one of the chief uses of roots. The roots also gather water containing mineral matter from the soil and this is absorbed by the plant to be changed by it into its food.

The stem of the goldenrod grows tall and erect, and the numerous leaves are arranged around it all the way from the bottom to the top.

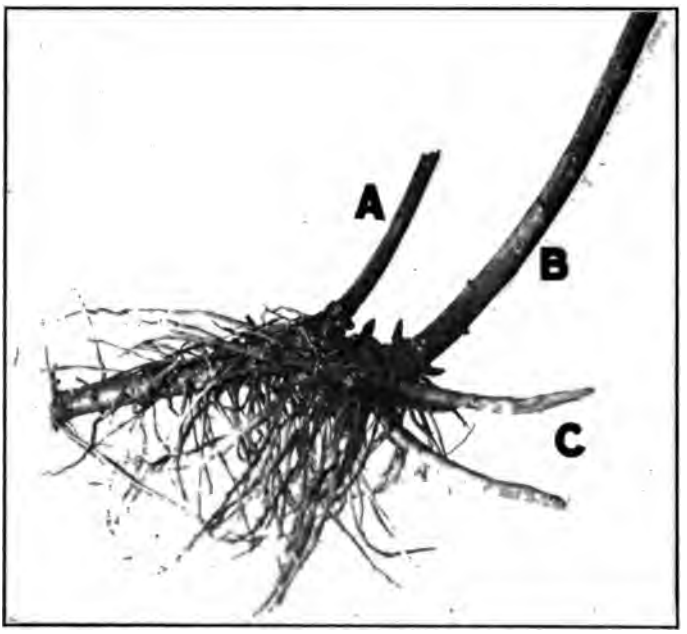


FIG. 26.—The underground parts of the goldenrod. *A*, last year's stem; *B*, the present stem; *C*, the stems which will grow next year.

The tall stem lifts the leaves above those of other weeds and thus supplies them with an abundance of sunlight. The stem also carries the food material from the roots to the leaves and returns the food products made in the leaves to the roots.

If we loosen the soil about the roots of a goldenrod plant and pull it up, we shall find that from the base of the upright stem there are several slender, white stems running out in all directions from the

parent plant. These stems are known as *underground stems* and keep the plant alive over winter when the upright stem is killed by the frost. From the end of each underground stem a new plant will grow up the next spring, and since there are several of these stems there will be several plants growing next year where there is only one now. This is an important method of reproduction in the

FIG. 27.—The monarch butterfly visiting a flower cluster of the goldenrod.

life of goldenrod plants and causes them to grow together in patches. It is seldom that you find one growing alone.

Thus, we see that the goldenrod stems are of two kinds. The erect stem lifts the leaves into the sunlight and supplies sap. The underground stem preserves the life of the plant over winter and multiplies the number of individuals.

The leaves are arranged in close spirals around the stem and project outward and upward. Is this a good arrangement for the maximum exposure of leaf-surface to the rays of the sun? Are the leaves arranged the same way on other kinds of plants which you find in the field?

The leaves make food for the plant, respire, and throw off waste products to the air. These important functions will be more fully

FIG. 28. Four different species of goldenrod.

described later on. If you examine the leaf closely you will find that there are small veins running all through it. These veins are bundles of very small tubes which conduct the sap through the leaf. Compare the arrangement of the veins in the leaf of the goldenrod with those in the leaves of other plants which you find in the field. The leaves around the base of the stem are withered. One of the causes of the death of these leaves is that they have been

shaded by the leaves higher up, and not being able to properly perform their work, they have died. Look for this same condition on other plants.

The Flower.—At the top of the plant many branches spread out from the main stem. These branches bear smaller branchlets upon which the little yellow flowers grow. How is the branch arrangement related to the leaf arrangement?

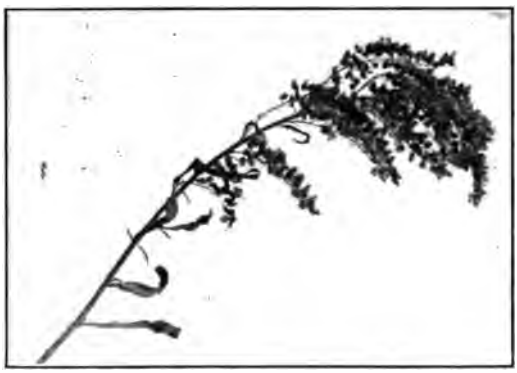


FIG. 29.—Late in the fall the seeds are ripe and the flower-clusters are heavy with their precious burden. The seeds are released, a few at a time, throughout the winter.

Project.—Find other plants in the fields which retain their seeds in the early autumn. Learn their names and discover how their seeds are carried to new localities. Report your findings to the class.

If it is a bright day you will notice insects working busily among the flowers of the goldenrod. They are gathering nectar and a yellow powder called pollen. As they crawl over the flower cluster some of the pollen which adheres to their bodies is dusted off and falls among other blossoms. In this way they carry pollen from flower to flower. If this pollen is not transferred from flower to flower no seeds will be produced. Some pollen may be carried by the wind, but insects are better carriers. Nectar, perfume, and color in flowers are the means of attracting insects in order that they may do this important work. The plant, however, exercises no

consciousness in securing this service. Does the arrangement of the flowers in a cluster make them more conspicuous than they would be if they were scattered over the plant?

The function of the flower is to produce seed. Find a plant that has produced its seed. Examine them closely and you will find that they are provided with a tuft of fine hair-like structures. If you blow them they will go sailing away. In a strong wind they may be carried a great distance. They finally fall to the ground where they remain until spring. If nothing disturbs them, they will germinate and establish another patch of goldenrods. Thus, the plant is distributed and increased in numbers by its sailing seeds.

Project.—Estimate the number of seeds produced by a single plant. How many plants would there be in five generations if all seeds should grow? Are there any more plants on the earth one year than another? Discuss this matter in class.

Relation to Environment.—The goldenrod is truly a North American flower. Its scientific name is *Solidago*. Under this genus 56 different kinds, or species, are known. Only a few species are found outside of the North American Continent. In Europe it is considered so beautiful that it is cultivated in flower gardens. Its various forms are adapted to grow everywhere from Canada to Mexico. Some live in swamps, some in deep woods, some on the dry western plains, but the untilled fields and fence rows furnish a home for the majority of species.

By means of its underground stems and extensive root system it makes preparation the fall before for the next season's growth. Early in the spring it sends up its wand-like stem and gets a good start before other plants which grow from seed can occupy the ground. The straight stems and long, narrow leaves enable the plants to stand close together and yet avoid shading one another. Its numerous, tufted seeds are distributed everywhere by the autumn and winter winds. It withstands successfully the frosts of winter, whilst the drought of summer hardly checks its growth. It is admirably fitted in every way to live in the North Temperate zone which is its home.

Project.—Make a collection of all of the different kinds of insects which you can find visiting the goldenrod. With the aid of the

teacher and books learn their names, mount them in a permanent case, and put them in the school museum.

Club Organization.—Organize a science or biology club in your school. Arrange for regular meetings. Appoint committees to carry out your business, projects, programs, museum organization, magazine subscriptions, and keeping of archives.

6. THE LIFE OF THE HONEYBEE

How has the honeybee solved the problems of animal life?

We have studied the life of one of our most common plants, the goldenrod. We will now study the life of a common insect, the

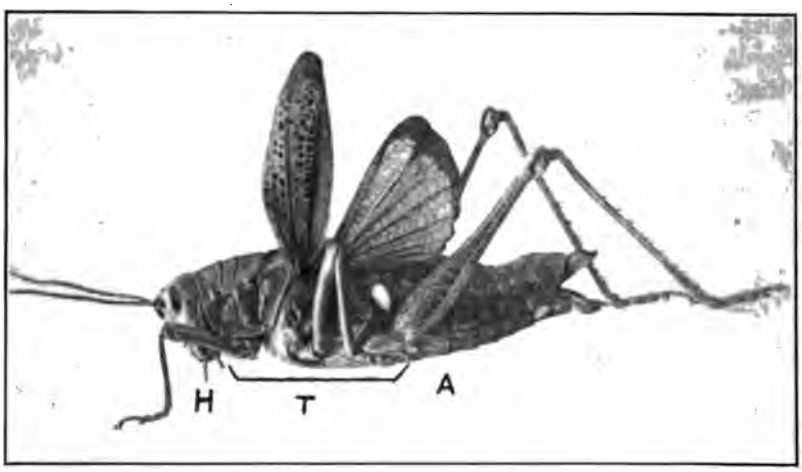


FIG. 30.—Side view of a grasshopper showing the parts of a typical insect. *H*, head; *T*, thorax; *A*, abdomen. Note the two wings, the three pairs of legs, the two feelers, and the two compound eyes.

honeybee. It may be seen on any bright day in the autumn crawling over the flower clusters of the goldenrod, dipping its tongue into flower after flower for nectar, and gathering pollen as it goes.

If we examine a bee very closely we will see that its body is composed of three distinct parts,—a *head*, a chest region or *thorax*, and an *abdomen*. Projecting forward from the head are two jointed feelers or *antennæ*. On each side of the head is a large compound eye

composed of many six-sided components closely fitted together. Between the two compound eyes there are three other single eyes but it will be difficult to see them without the aid of a magnifying glass. On the under side of the bee's head is its mouth. Its structure is shown in Fig. 32.

Attached to the back of the thorax are two pairs of wings which are folded along the body when at rest and are hooked together along their adjacent edges when the bee is in flight. Attached to

FIG. 31.—The head of the cicada showing the five eyes which are typical of insects. The compound eyes are like large knobs on the sides of the head. The simple eyes are in the center of the top of the head and look like small round beads.

the under side of the thorax are three pairs of jointed legs which are used for a great many purposes,—such as walking, moulding wax, brushing and cleaning the body, gathering pollen, storing pollen in the comb, and carrying foreign bodies from the hive. The antennæ, mouth-parts, and legs are called *appendages*.

The abdomen has no appendages. It can be very clearly seen to be composed of rings which seem to telescope into each other. These rings are called *segments*. On either side of the abdomen, in each segment, there is an opening known as a *spiracle*. These spiracles

lead to a complex system of small tubes called *tracheæ* which ramify through all parts of the insect's body. They are the breathing organs. If you watch a live bee you will see the abdomen pulsate, somewhat as we expand and contract the chest when breathing.

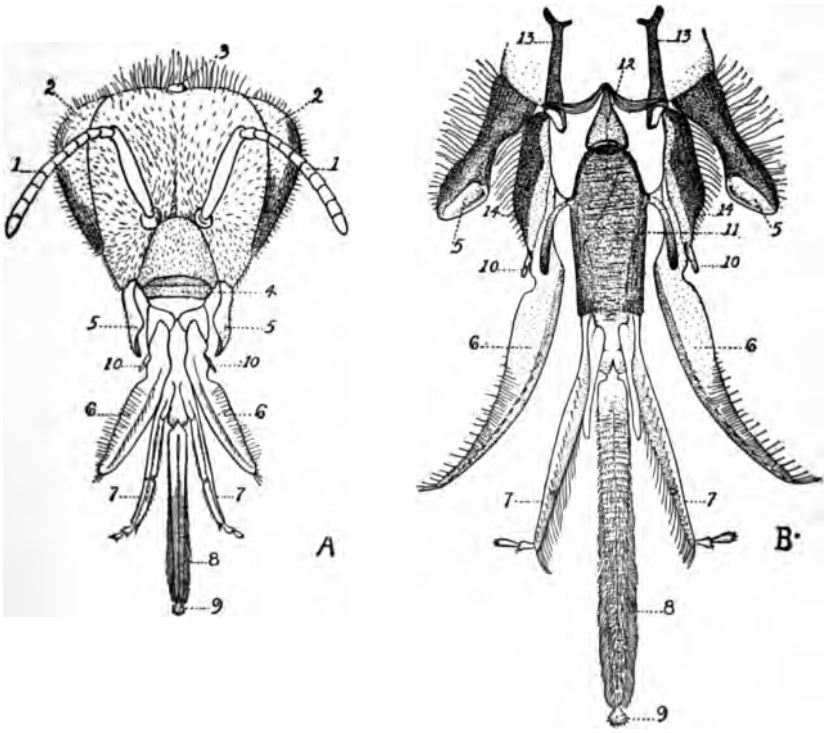


FIG. 32.—Head and mouth-parts of the honeybee. (*From Lochhead, after Herms.*)

1. antennæ
2. compound eyes
3. simple eye
4. labrum
5. mandibles
6. maxillæ
7. labial palps
8. hypopharynx
9. tongue tip
10. maxillary palps
11. mentum
12. submentum
13. cardo
14. stipes

The entire body of the bee is covered with short hairs. When the insect is on the goldenrod these hairs brush off great quantities of pollen so that the bee assumes a golden yellow color. This pollen

is scraped off and stored in "baskets" on the hind legs and carried to the hive. Watch a bee and see just how it does this.

In the hive there are three kinds of individuals,—the queen, a few hundred drones, and twenty to fifty thousand workers. The queen is the mother of the entire colony. Her life work is to lay eggs. The workers are females which have been raised in smaller cells than those in which the queen was raised. They have also received a different kind of food. Normally, they do not lay eggs but do all the other work of the hive. The drones are males and one of them, or one from some other hive, fertilizes the virgin queen on her "wedding-flight" after the old queen has led a swarm of old bees out of the hive.

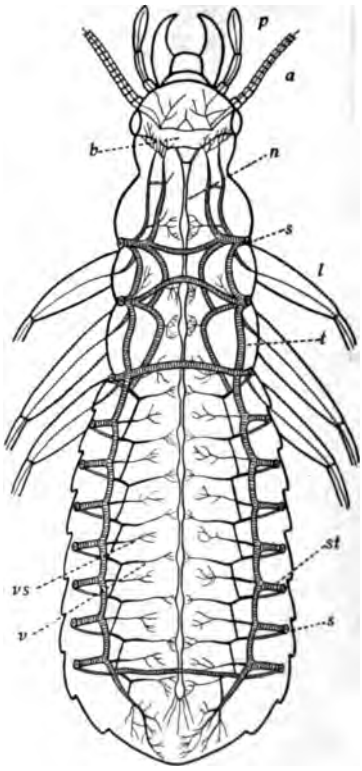


FIG. 33.—Diagram of the tracheal system of an insect. Note the branches (*st*) from the spiracles (*s*) to the main trunks (*t*), and the branches to the palps (*p*), antennæ (*a*), brain (*b*), nerve cord (*n*), and to the organs of the abdomen (*vs*, *v*). (*After Kolbe, from Folsom.*)

The substances found in a hive are ***honey***, ***pollen***, ***propolis***, and ***wax***. The honey and pollen are gathered from flowers and are used as food. The propolis is a resin or gum that is gathered from plant buds and other sources and is used to seal up cracks in the hive. Any animal,—such as a bumblebee or mouse which comes into the hive and is killed by the bees and can not be removed, is sealed over with propolis. Why is this done?

Wax is secreted in glands called "wax-pockets" on the under side of the abdomen. It is used for building comb in which to raise brood and store honey and "bee-bread" which is a mixture of honey and pollen.

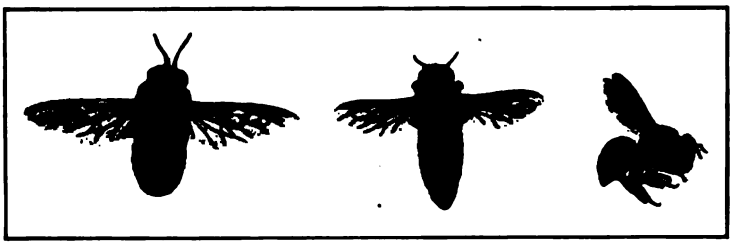


FIG. 34.—The three types of bees found in a hive. From left to right they are,—a drone, a queen, and a worker. What part does each play in the society of the hive?

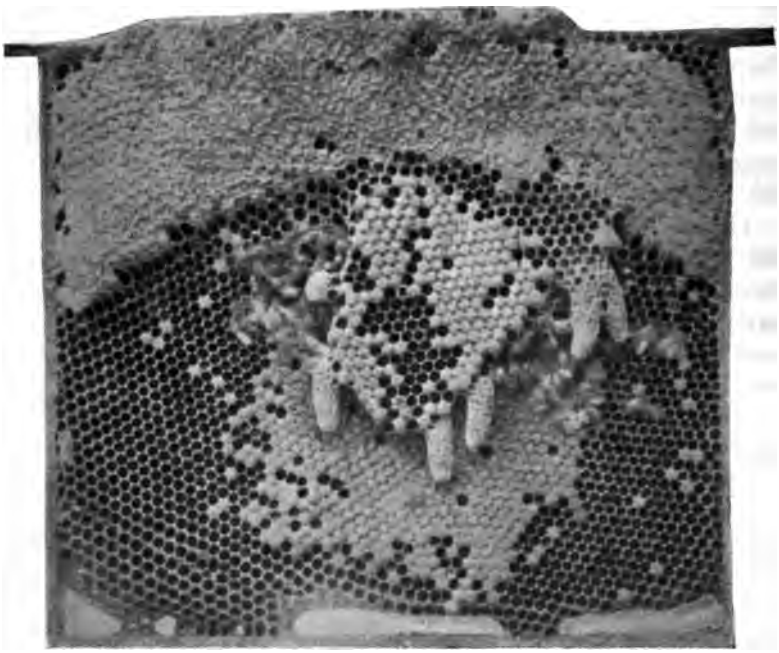


FIG. 35.—A section of honeycomb showing capped honey at the top, sealed and unsealed brood, and queen cells. (*From Root, A B C of Bee Culture.*)

The cells are of two sizes. In the large cells unfertilized eggs are laid, which develop into drones. In the small cells fertilized eggs are laid which develop into workers. An egg, in either case hatches into a legless, white grub called a *larva*. It is cared for by the young bees and in a few days becomes full grown when it is sealed over with a wax cap. In about 21 days the bee gnaws its way out fully developed. A drone emerges in about 25 days and a queen in about 16.

Swarming is the natural method of increasing the number of colonies, but in the *apiary* (bee farm) man has other methods of

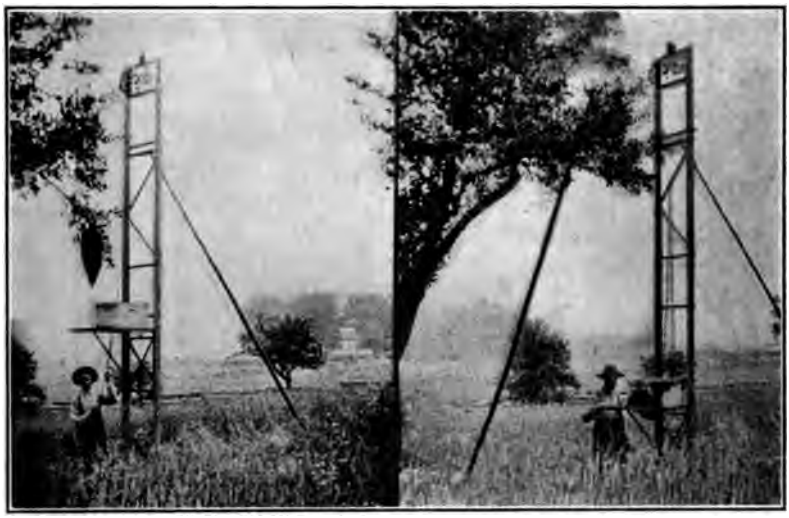


FIG. 36.—An apparatus for hiving a swarm. Be able to describe how it is used. (*From Root, A B C of Bee Culture.*)

increasing the number of his hives. Two or three weeks before the bees are ready to swarm the queen lays eggs in a number of large cells that have been prepared for raising queens. One of these eggs develops into a young queen which take sthe place of the old one when she leaves with a swarm.

The bees usually choose fair weather for their swarming day. The old bees and queen emerge from the hive with a great buzzing and fly in great confusion in the vicinity of their hive. They soon cluster near by around their queen in a dense mass which is

known as a *swarm.* If they are not hived within an hour or two they usually fly away and cluster again at some distance. Finally, they find a hollow tree or some other cavity and start a new colony. The wild bees on this continent have escaped from bee-keepers. They are native to the Eastern Hemisphere.

There are many ways of capturing a swarm but probably the surest is to clip the wings of the queen so she can not fly. When the swarm

FIG. 37.—An observation hive.

comes out she will be found crawling around in front of the hive. The bees will cluster as usual but when they find their queen is not with them they return to the old stand. In the meantime an empty hive has been placed on the old stand, and the old hive removed. When the bees return the queen is placed in the new hive with the returning bees, and the swarm is hived. If the keeper does not wish to increase the number of his colonies he may later kill the old queen

and set the new hive on top of the old hive, and, thus, reunite the bees which now have a young queen.

Economic Importance.— The bee-keepers of the United States produce annually more than $22,000,000 worth of honey and wax, but millions of pounds of nectar remains ungathered in the fields because there are not enough bees to secure it. The number of hives could be increased many times over, if properly distributed, without crowding. Bees are very important pollinators of all kinds of fruit and berries and many kinds of other crops. Every orchardist should keep bees to insure proper pollination of his fruit blossoms. Every high school and college should have an observation hive where the work of the bees may be watched by the students.

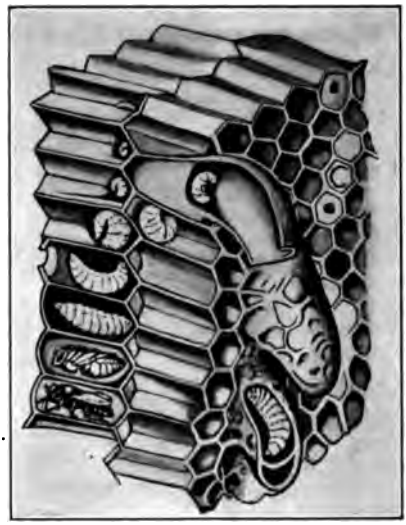


FIG. 38.—The life history of a bee. An egg is laid at the bottom of a cell; it hatches and becomes a larva; the larva is sealed in; it spins a silken cocoon about itself and becomes a pupa. On the twenty first day the fully developed bee emerges from the cell. (*From Folsom, after Benton.*)

Field Trip.—The class should visit an apiary if possible.

Project.—If there is no observation hive in the laboratory, appoint a commitee to investigate ways and means of securing one.

Class Project.—Make a list of all of the kinds of flowers which you see bees visiting. Which do they visit the most?

Report.—Someone may look up the life history of the bumble bee and compare it with that of the honeybee. Several species of bumble bees are native to North America.

Write to the U. S. Department of Agriculture, Washington, D. C. for their publications on the honeybee.

UNIT II. THE RELATION OF LIFE TO FOOD

How Have Plants Solved the Problems of Obtaining Food?

7. THE STRUCTURE AND WORK OF ROOTS

What is the work of roots, and how are they fitted to do this work? Roots may be classified as either *primary* or *secondary*. They are

Fig. 39.—Secondary roots growing from the base of a corn stalk. Of what special value to the stalk are these roots?

primary if they are the original seed roots or their branches. They are secondary if they spring from some other source as from the stem

as do the brace roots of corn, or from the leaf as in the live-forever (Fig. 211).

FIG. 40.—Tap root of sweet clover. This root is one season old. Note the two buds at the crown which will send up shoots to become the plant of the second season.

If the first seed root is longer than its branches, as in the case of the carrot or most tree roots, it is called a *tap root*. Such roots penetrate the soil to great depths and are often fleshy and filled with

food. Plants which possess them are often adapted to withstand drought by sending their roots deep enough to secure water in the dryest weather. The roots of alfalfa and sweet clover are of this type.

If the roots are all long and slender as in the grasses they are called *fibrous roots*. These roots, as a rule, do not penetrate the ground so deeply as the tap roots. There are some notable exceptions, however, —such as the sand hill grasses and kaffir corn.

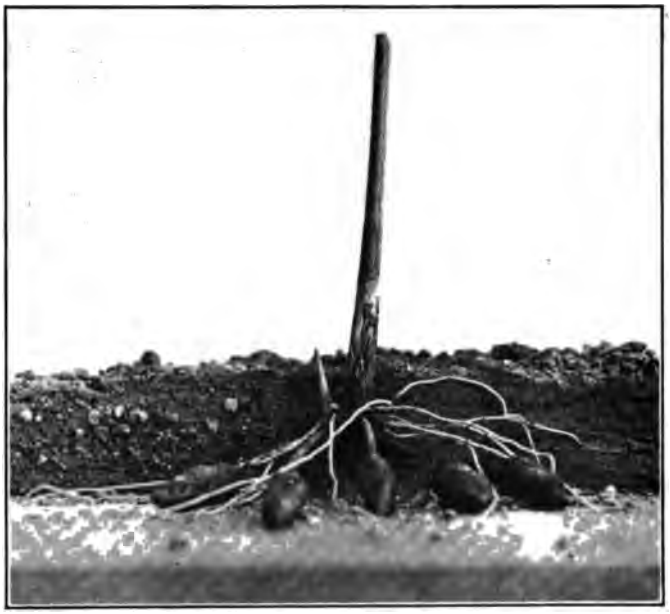


FIG. 41.—Pleshy roots of the fascicled type taken at the end of the season and planted in the laboratory. Note the white roots which have grown out, long and slender, from the main stem and the shoot at the side of the old stem. This is one of the wild *Umbelliferæ*.

Either the tap roots or the fibrous roots may become swollen and contain stored food or water. Examples of this type are the beet, carrot, radish, sweet potato, dahlia, and asparagus fern. Such roots are said to be *fleshy*.

Roots may also be classified according to their length of life.

Upon this basis plants are classified as *annuals*, *biennials*, or *perennials*. An annual is a plant which completes its life in one season and dies, as the mustard or rag weed. A biennial is a plant which lives during a part of two growing seasons,—as the beet or fall wheat.

FIG. 42.—Fleshy roots of the fascicled type for water storage. These roots were placed in a drawer of the author's desk after the photograph was taken and remained succulent for six months before drying out. They are from the common asparagus fern. Can you secure one for the laboratory for experimental purposes?

Such plants often store food in fleshy roots or stems the first season, and produce seed and die the second.

Trees are perennials and live to be many years old. Other perennials like the goldenrod die to the ground every winter but

continue to live below ground and shoot up in the spring year after year.

Many perennials and biennials and a few annuals, as well, exhibit

FIG. 43.—A rosette plant—the dandelion.

a peculiar phenomenon known as *root pull*. These plants are usually of a type known as *rosette plants* and are "stemless." Their leaves spread out on the ground like a rosette, and they apparently

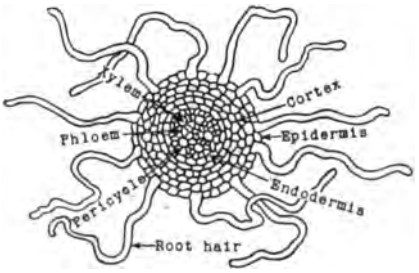


FIG. 44.—Cross section of a young root. About how much is the surface increased by the addition of the root hairs? Of what value is this increased surface? (*From Stevens.*)

have no stem. The dandelion and peppergrass are examples. This is because the central axis of the root contracts longitudinally and draws the stem down into the crown of the root as fast as it grows.

These plants often send up a long stem the second season or later on in the same season that the rosette is formed. It is obvious that it will be more difficult for a browsing animal to eat off a rosette plant than one which does not "hug the ground" so closely.

A cross section of a young root is shown in Fig. 44. It will be seen to be composed of three parts: the *epidermis*, the *cortex*, and the *stele*.

FIG. 45.—Root hairs of a pumpkin seedling clinging to soil particles.

The epidermis is the outermost layer of cells and protects the inner parts. Some of the cells of the epidermis have longhair -like processes running out from them. These processes are called *root hairs* and come into direct contact with the soil particles. They are the absorbing organs of the root.

The cortex is a thick region between the epidermis and the stele. It is prominent in fleshy roots and serves as a storehouse for food to be used later by the plant. Sap passes through it to the stele, traveling from cell to cell.

The stele is the central part of the root and is filled with fine tubes through which the sap passes. The woody tissue or *xylem* is the more central and carries the sap up to the plant. It is surrounded by *bast* or *phloëm* cells which carry sap down to feed the roots. We shall learn more about xylem and phloëm when we study the stem.

The four most important uses of roots are anchorage, absorption, reproduction, and storage.

Anchorage.—One of the most conspicuous differences between plants and animals is that animals are free to move about while plants are anchored to one place. Try to pull a large weed out of the ground, and you will probably be surprised to note how firmly it is held in place. Browsing animals and severe storms would uproot many plants if it were not for this firm anchorage.

Absorption.—Pull up a plant and immerse the root in some red ink. In a short time the ink will be seen in the veins of the leaves. This illustrates the fact that water is being constantly taken up by the roots of plants and passed on to the leaves. Mineral matter which is contained in the soil water is thus carried to the leaves to be made into food. The root, it seems, is able to exercise some control over the kind and quantity of mineral salt that is absorbed, but only to a limited extent.

Osmosis is the name of the process by which roots take up water. It may be illustrated in the manner shown in Fig. 46. Sugar solution is placed inside the carrot, and water passes in faster than the sugar passes out. This causes the sugar solution to increase in volume and to pass up the glass tube. *If two solutions of crystalline substances of unequal density are separated by a permeable membrane, both liquids will pass through; but the less dense of the two will pass through the more rapidly. Protoplasm is not crystalline and does not pass through vegetable or animal membranes.* This is the law of osmosis and is the cause of sap pressure in roots. The walls of the root hairs constitute the first membrane through which the soil water passes on its way to the plant. Acids pass out through the root

hairs and dissolve the soil particles, releasing plant food. No sugar is permitted to escape, however. This indicates that the living substance of the root is able to exercise some control over exosmosis as well as over what comes in.

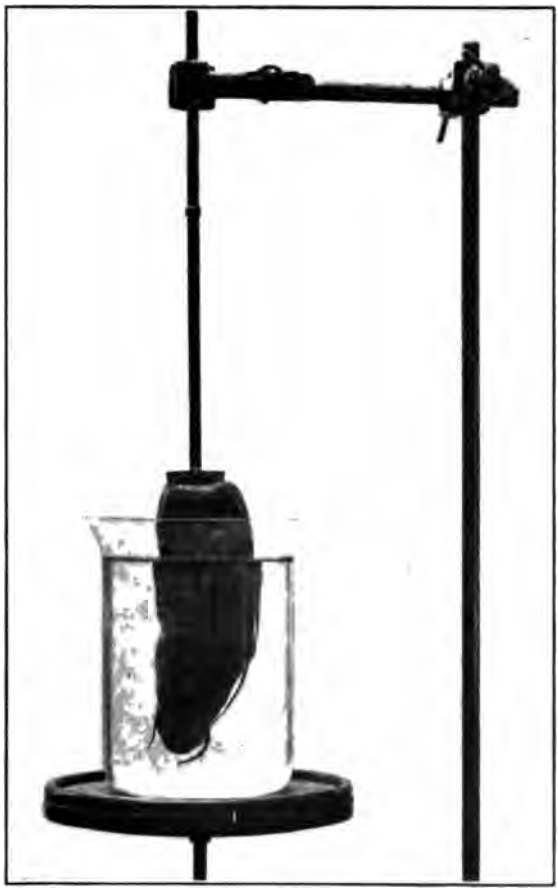


FIG. 46.—A carrot osmometer. Appoint committees to set up a few of these as a demonstration of osmosis for the class.

Reproduction and Storage.—These uses are closely associated, and we will discuss them together. The fleshy roots of the dahlia

and sweet potato contain much food which has been prepared by the leaves and stored over winter in the roots. This is a means of keeping the plant alive over winter. Since there are several such roots on each plant, and each root may produce one or more plants the next summer, it is also a means of reproduction. Plants which

FIG. 47.—A raspberry patch in winter. These stems have sprung from the roots of the plants of the season before. Do they help each other to stand erect?

live in deserts may store water in their roots to enable the plant to live through the season of drought.

The roots of cottonwoods, lilacs, and blackberries, when injured, send up shoots and may in time produce a great many plants growing in an association,—all the offspring of one parent. Vegetables,

like rhubarb; horse-radish, sweet potato, and asparagus are commonly propagated by planting portions of the root of a parent plant.

Committee Projects.—Evaporate such roots as the carrot and determine what per cent of them is water. Plant such roots as the apple, willow, dahlia, sweet potato, beet and determine their ability to reproduce the plant. Test such roots as the radish, beet, turnip, and parsnip for the presence of fats, proteins, and carbohydrates. See laboratory food tests at end of Study 15, Make *pocket gardens* to study root hairs. Always report on your projects to the entire class.

Laboratory Work.—Fleshy, tap, fascicled, and fibrous roots may be drawn in cross section and outline. Root hairs may be viewed under a magnifier and drawn. In doing laboratory work the student should have as few directions as possible. Each student should make his work show his individuality.

Field Work.—Pull up various weeds by tying the hook of a draw scale to them and noting the reading when the weed comes out of the ground. Bring the weeds and the record to class.

8. SOILS AND CONSERVATION

What is the relation of plants to soils?

We have seen how the plant is anchored to the soil by its roots and how it gets its mineral food and water from it. The soil, therefore, is of great importance to the plant. In this study we shall try to understand something of the nature of soil and how it may be maintained in a condition to yield the best crops.

There are many forms and grades of soil, and most soils are complex mixtures of many types. There are, however, three classes of material entering into the composition of soils which we may define. They are *sand*, *clay*, and *humus*.

Sand.—All soil was originally solid rock. This rock, upon being weathered, became soil. Sand results from the weathering of rocks containing quartz. Pure sand is composed of fine particles of quartz rock which have not yielded to chemical disintegration and are too hard to be reduced to a powder by the ordinary processes of weathering.

Clay differs from sand in that it is made from rocks of the feldspar type by the action of the chemical agencies of weathering. The chemical composition of sand and quartz rock is the same, whereas the chemical composition of clay and feldspar rock is not the same. This chemical disintegration reduces clay to a very fine grained con-

dition. The carbon dioxide gas of the air, which is in solution in rain water, is one of the chief disintegrating agents in the formation of clay.

There are many rocks which can not be easily classified as quartz or feldspar. When these rocks weather the soil varies between sand and clay. Granite contains both quartz and feldspar and upon weathering forms a rich sand and clay soil. Limestone weathers readily under the action of water containing carbon dioxide. Much of the limestone is dissolved and carried away by the water, but that which remains forms a very fertile soil resembling clay.

Humus.—The third type of soil is formed by the decay of the bodies of plants and animals. It is black in color and very fertile. It is seldom found pure, but old lake beds which have been filled in by the growth of vegetation and then drained are nearly pure humus. Soils where plant growth has been abundant are rich in humus. Where plant growth has been limited, as in deserts, humus is not plentiful.

Most soils are a mixture of sand, clay, and humus. Such soils are called *loam*. It is the universal soil mixture and varies with the proportions of the three types entering into its composition. When sand predominates the soil is said to be a *sandy loam*. When clay predominates it is said to be a *clay loam*. Sandy soils are said to be *light* because they work easily, and clay soils are said to be *heavy* because they are sticky and are worked with difficulty; but in reality a cubic foot of sand weighs more than a cubic foot of clay.

Soils may be classified as *sedentary* or *transported* according to whether they remain where they are formed or are carried by glacial ice, rivers, or wind. *Glacial soils* are found in Canada and the United States north of the Missouri and Ohio rivers. In the New England States much of the soil has been removed by ice but the greater part of the rest of this territory is covered with rich glacial soil which has been brought down from the north.

Alluvial soils have been deposited from water. The soil that is carried from the surface of the land by running water is dropped in lakes and on the flood plains of rivers. It is a fine grained, fertile soil and is usually of great depth.

Æolian soils have been deposited by wind action. The prairie soils of the western states have been affected in this way. Along the Missouri and Mississippi rivers a yellowish-brown, very fertile soil, called *loess* (lĕs) is found. It has been formed by both wind and water activities. Extensive areas of it are found in the valley of the Yellow River in China.

Sedentary soils remain where they are formed and are of the same material as the rock beneath them. The limestone soils of the famous blue grass region of Kentucky are of this type.

The fertility of any soil depends in a large measure upon its *chemical* and *physical* make up. A good soil must contain the elements necessary to build up the tissues of plants. A table of the elements found in living bodies is given on page 4. These elements are usually found in sufficient quantity in new soil, but after cultivation for a few years certain elements may become scarce. Phosphorus, potassium, and nitrogen are absorbed in considerable quantity in the form of their soluble salts. If the crop is removed they are taken away from the land and when their quantity is too much reduced the growing plants starve and lose vigor. These elements may be restored to the land by plowing under green crops, applying barnyard manure, and adding commercial fertilizers which contain them. It is not enough that these elements be contained in the soil. They may be locked up in sand particles and, hence, may not be available. These elements must be in the from of soluble salts or they can not be taken up by the root hairs.

Texture.—The physical condition of the soil has much to do with rendering the chemical elements available for plant uses. The term *soil texture* refers to the size of the particles. A fine soil exposes more surface for the root hairs to work on than a coarse soil. More water is held in a fine soil than in a coarse one.

Water may exist in soil as *free water*, *capillary water*, and *hygroscopic water:*

Free water is moved about under the influence of gravity and often emerges from hillsides in the form of springs.

Capillary water is not controlled by gravity but moves like the oil in a lamp wick and goes up as well as down. Its movement tends to keep all parts of the soil equally moist. Water is con-

stantly rising from the lower layers of the soil to near the surface. In this way much of it is lost by evaporation. In our great plains states where the rainfall is not plentiful it is advisable to keep the upper part of the soil finely pulverized so that this capillary water will not pass through it and evaporate. This upper layer of fine soil is called a *mulch*, and the practice of keeping a mulch on the surface of the ground is called *dry land farming*. By this practice the productivity of dry soils is greatly increased.

FIG. 48.—An experiment to demonstrate the use of a mulch. Place equal amounts of soil in both pans, wet them equally with water, and weigh. They should weigh equal. Place a weighed amount of sawdust on one pan and none on the other. Set them both away and weigh again from time to time. What effect does the sawdust have on evaporation?

Hygroscopic water is held in a loose chemical union with the particles of the soil. It is not free to move from particle to particle but can be driven out by heating. Ordinary table salt is capable of absorbing and retaining water in this way.

Structure is a term applied to the arrangement of the soil particles in clods or granules. If the particles are arranged in granules the structure is good, and the soil is said to have good *tilth*. Sand and humus improve the structure of the soil. Clay tends to cause the soil to be sticky when wet and to form clods or pack when dry.

The things which tend to bring a compact soil back into good condition are (1) fall plowing, (2) working green and stable manure into the soil, (3) better drainage, (4) the addition of lime, (5) rotation of crops, especially hay and pasture crops. A clay soil should never be plowed when it is too wet as this impairs the structure. The ill effects of this may last for several years.

A good soil should be one in which air circulates freely. Corn and cotton will not grow on wet land because water excludes air from their roots. Some plant roots like those of the cat-tail and cypress are adapted to live under water, but the majority of land plants require air for their roots.

Plants like peas, beans, and clover, which bear their seeds in pods, have little nodules containing bacteria growing on their roots. These bacteria are able to extract nitrogen from the air and build it into salts which are given up to the plant roots on which they grow. Plants of this character are valuable soil enrichers where the supply of nitrogen is insufficient.

Most people think of soil as inert and dead. It is, in fact, very much alive. It swarms with microscopic life. These minute organisms are of great importance in preparing the chemical constituents of the soil for absorption by plant roots. Humus favors the activity of these organisms, and, hence, a fertile soil must be well supplied with humus.

FIG. 49.—The nodules on the roots of this pea plant are the homes of bacteria which gather nitrogen from the air. On older plants they are much larger.

Committee Projects.—Secure samples of various kinds of soils. Bottle them, label them, and put them in the museum case for future reference.

Carefully remove such plants as clover, alfalfa, and peas from the soil and bring them to class to demonstrate the presence of nitrogen forming bacteria in their nodules.

Laboratory Work.—Committees may be appointed to work up experiments on capillarity, percolation, the use of a mulch, presence of water in apparently dry soil, relative ability of soils to hold water, amount of organic matter in various soils, mechanical analysis of soil by means of sieves.

Note to Teacher.—Specimens of feldspar, quartz, limestone, granite, and peat should be secured and shown to the class when soils are studied.

9. THE STRUCTURE OF STEMS

What is the architecture of plant stems?

The plant stem contains many different kinds of cells and tissues, which are not uniform in their occurrence in the stems of different species of plants. We will first consider a young tree stem of one year's growth as shown in Fig. 50. Reckoning from the center of the stem to the outside we may distinguish three zones,—namely, the *pith*, *wood*, and *bark*, as labeled at the bottom of the figure. The pith is composed of large, thin walled cells which have changed little from their original form when the parts of the stem were being developed from the *fundamental cells* out of which all of the cells of the stem have been formed.

Certain portions of the pith extend out into the wood and bark and are called *medullary rays*. They are greatly flattened bands of fundamental cells which have been pressed upon laterally by the growth of the woody tissues. It is the medullary rays which give to quarter sawed oak its beautiful grain effect.

The cambium layer which separates the wood from the bark is the region of growth in the stem, bark being formed on its outer side and wood on its inner. Which is produced in the greater abundance?

Xylem is the name given to all woody tissue, the bark being known as *phloëm*. The inner layer of wood which is next to the pith and is grown the first year is known as *procambium* because it does not develop from cambium, but all other wood in the stems of our trees is developed from the inner cells of the cambium ring.

Wood contains, among others, three types of cells which are worthy of special mention. They are shown in Fig. 51, and are all developed from cambium. The *tracheal tubes* (A) are formed from a chain of cells by the breaking down of their end-cell-walls, thus a tube is composed of several cells. The *tracheids* (B) are cells which have elongated, and their ends have pushed past each other so that the end-cell-walls are diagonal and are pitted. Sap may pass through these pits from cell to cell. This gives the name

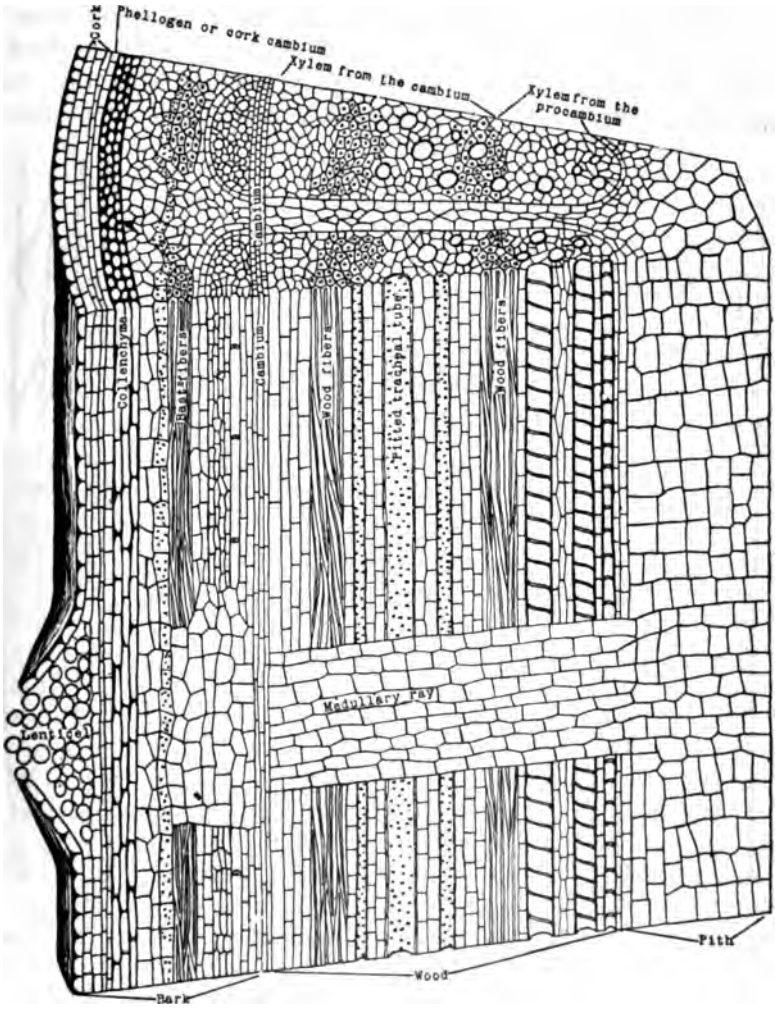


FIG. 50.—Sterogram of a young tree stem to show the arrangement of its parts. (*From Stevens.*)

pitted tracheids to these cells. They assist the tubes in the circulation of sap. The *wood-fiber-tracheids* constitute the third type. They are like the pitted tracheids but have no pits and have thick walls. Their function is to give strength to the tree rather than to carry sap. When each type is mature the protoplasm within dies,

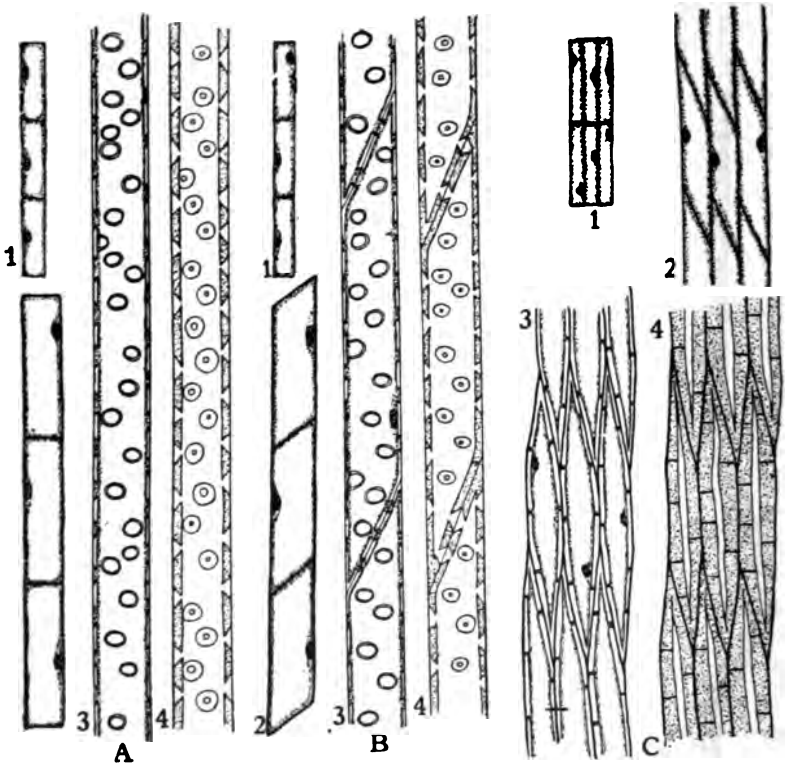


FIG. 51.—Three diagrams to show four stages in the development of (*A*) a tracheal tube, (*B*) a tracheid, (*C*) a wood fiber. (*From Stevens.*)

leaving the cell wall to remain as dead material. It is remarkable that all sap movement in plants, except that in growing tissues, is through dead cells.

The bark contains *epidermal cells* in its outermost layer. These soon die and break up and are not found in old stems. Beneath these

are the *cork cells*. Examine a piece of cork with a microscope. In the inner region of the bark are the *bast fibers* which are somewhat like the woody tracheids, but are usually more slender. The *stone cells* are tough walled cells which give rigidity to the bark. Near the cambium ring are the *sieve tubes*. These are similar to the tracheal tubes, but the cross walls remain in place, and they are not so large nor are they so abundant. Many openings occur in the cross walls and this gives the tubes their name of sieve tubes. They are the avenues through which the sap of the bark flows down to the roots and other places, whilst the tracheal tubes and pitted tracheids of the wood carry sap up to the leaves. Why should the tube system of the wood be more extensive than that of the bark?

Annual Rings.—One of the most striking characteristics of tree stems is the series of rings (annual rings) which compose the wood. If these rings are examined closely they will be seen to be composed of alternate bands of large and small pores in the stems of the broad leaved trees, and of alternate bands of large and small wood fibers (tracheids) in the evergreens. The large pores and cells are formed in the spring and the small ones during the summer. These pores are the tracheal tubes which we have mentioned. As a rule they do not occur in evergreens.

We recognize three types of annual rings as shown in the illustration. (1) The *ring porous* woods where the pores are alternately large and small, (2) the *diffuse porous* woods where the pores are about equal throughout the year but the tracheids are unequal, and (3) the wood of evergreens where the pores are absent and the rings are formed by an unequal growth of the tracheids.

How can you tell the age of a tree by examining the top of the stump? Why does a tree die when it is girdled? Place a branch of willow in water top end down and see if it will grow. In this case, which way is the sap flowing in the wood and bark? Place some red ink in the water and in about an hour cut the stem and see what parts are stained. The redwood tree has a relatively large amount of supporting tissue, and the grape vine has a relatively large amount of vascular tissue. Account for this. Discuss the advantages and disadvantages of the vine and the tree trunk as types of stems.

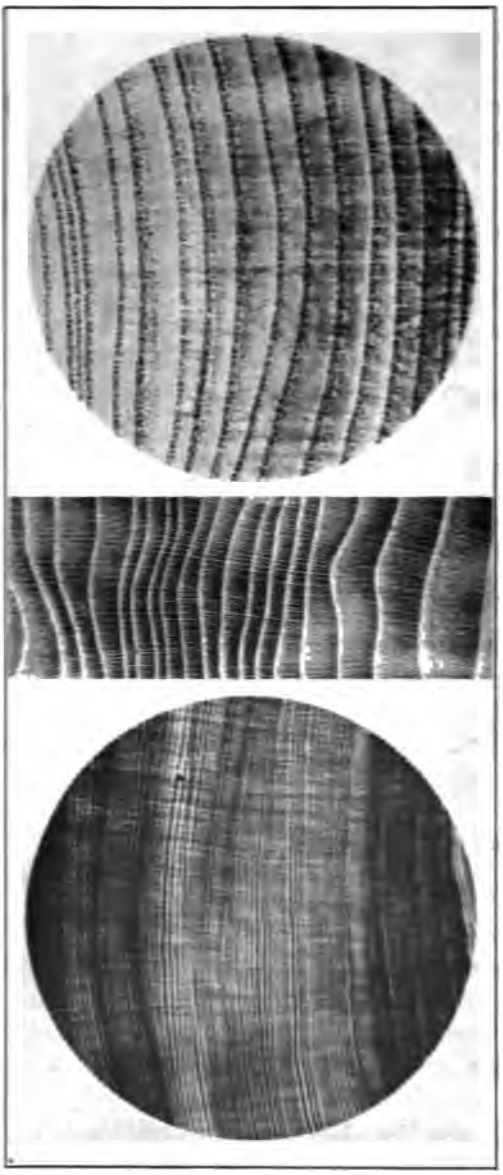


Fig. 52.—*Three types of annual rings.* Ring porous wood of alianthus above. *Diffuse porous wood of sycamore in the middle.* Cross section of redwood to *show absence of pores in the evergreens below.*

Endogenous Stems.—A broken section of a corn stalk is shown in the figure below. In this type of stem the epidermis and cortex

FIG. 53.—Photograph of a broken corn stalk to show the arrangement of the cortex, pitch, and fibrovascular tissue. Note the fibers which protrude from the pith.

FIG. 54.—Erratic branching of the sumach; due to the fact that it has an indeterminate annual growth.

form a tough ring around the outside. The inside of the stem is filled with pith tissue. In this pith the fibrovascular bundles are

scattered. There is no cambium ring, and hence the stem does not grow continuously but reaches a certain size and stops. Stems like that of the corn plant are said to be *endogenous* (Gr. *endo* = within + *gens* = a producing). Stems like that of the oak are said to be *exogenous* (Gr. *exo* = outside + *gens*). These two types of stems are representative of the two great classes of flowering plants,—the MONOCOTYLEDONEÆ and the DICOTYLEDONEÆ respectively. More will be said about these classes later on. See Fig. 212.

Classification of Buds and Branch Arrangement.—Growth may be *determinate* or *indeterminate* according to whether the growing shoot forms a terminal bud and stops growing or grows until the frost kills it. The illustrations show the terminal bud of cottonwood and the form of branching resulting from the indeterminate growth of the sumach. What effect has the presence or absence of a terminal bud on the form of the tree?

Buds which occur on the sides of the branch are known as *lateral buds*. They may be arranged *oppositely* as in the *Weigela* shown in the figure, or *alternately* as shown in the basswood of the same figure. Bud arrangement is dependent upon leaf arrangement,—the alternate buds being arranged in spirals, as are alternate leaves, around the stem. Opposite budded stems very seldom form terminal buds, and when they do (as in the lilac) they form a pair. Bring some branches to the laboratory which will show the type of growth resulting from the above mentioned bud arrangements.

Lateral buds may be of three types: (1) *axial*, in the axils of leaves; (2) *accessory*, when more than one bud is formed in the axil to provide for a second growth in case the main buds are caught and killed by an early frost; (3) *adventitious*, when they grow at any place along the stem not in the axils of leaves. Most plants can not produce adventitious buds; but elms, willows, and plums produce them readily. Of what advantage may they be?

Field Trip.—It may be convenient to make a trip for the purpose of studying stems, buds, and branches.

The names of the common trees and shrubs may be learned as a project, or on excursions. Is it worth while to know them? Why is it?

An attempt may be made to learn to recognize the common woods used in

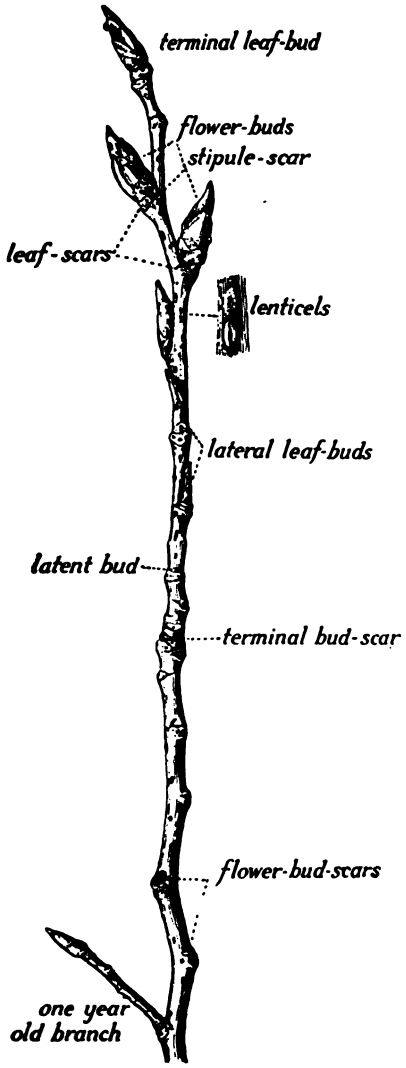


FIG. 55. FIG. 56.

FIG. 55.—A winter twig of the cottonwood of two years' growth. What is the function of the lenticels (See also Fig. 50)? (*From Robbins, after Longyear.*)
FIG. 56.—Opposite buds of weigela and alternate buds of basswood.

making furniture and in building by their grain. This is usually a difficult study for some students.

Laboratory Work.—Lantern slides showing stem structure may be shown. Cross sections of stems may be viewed under the microscope. Count the rings in cross sections of woody stems to determine their age.

FIG. 57.—An opening combination bud of hickory. Note the leaves unfolding, the flowers in the form of catkins, and the bud scales which are ready to fall off.

10. THE WORK OF STEMS

What is the relation of the plant stem to the rest of the plant?

Stems may be divided into four classes according to the work they have to do: (1) erect, (2) climbing, (3) prostrate, (4) underground.

I. ERECT STEMS.—Most stems are of this class. The primary purpose for which the stem was developed in the plant kingdom was to lift the leaves above the green tissue of other plants and thus secure more sunlight. The first plants that lived on the earth had no stems. The development of fibrovascular tissue made it possible for sap to circulate easily, hence it became possible to have the leaves

a considerable distance from the roots which supply them with moisture. The development of fibrovascular tissue for the circulation of sap, therefore, made the stem possible.

In the forest there is a quiet but intense struggle to secure sunlight. Those plants which fail in this struggle must devise methods of living in the shade,—*i.e.*, become shade plants, or perish. Every oak tree that grows to maturity in the forest does so by shading to death hundreds of other plants which contend with it for light.

FIG. 58.—An old pin oak tree, an example of an erect stem which survives the winter and begins growing where it left off the summer before. It is much more successful in obtaining sunlight than the grass and weeds which are its competitors.

The stems of herbs are not woody and die in the fall of the year. Most herbs have given up the struggle to live in the woods and seek the open fields and fence rows, but some of them have acquired the ability to live with a small amount of light and cover the floor of the forest in spite of the shade. Many saplings (young trees) are able

to grow in the shade of their elders for many years, waiting their opportunity to shoot up and spread their leaves in the sunlight.

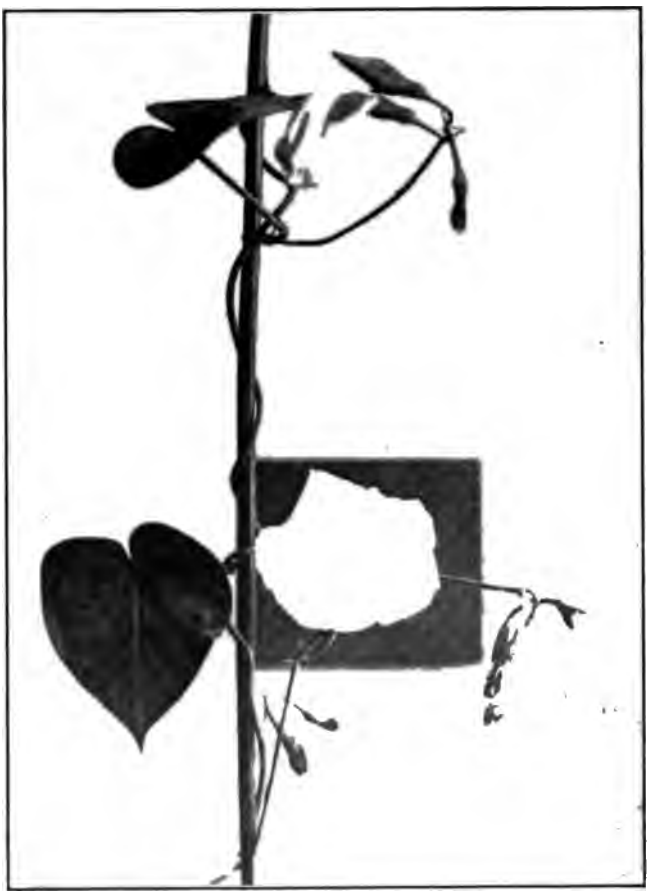


FIG. 59.—The morning-glory climbs by twining from left to right. The hop vine twines from right to left. Try to make a vine twine in the direction contrary to its nature. Report your results

II. CLIMBING STEMS. Much food matter is required to build up the trunk of a tree. Some plants like the bamboo conserve much of this material by having long, hollow stems which are quickly and

economically built up, but the vines have a still better way. They climb over other plants and thus are required to use more energy in lengthening their stems and less in increasing their diameter. Vines are especially characteristic of the tropics, where they live

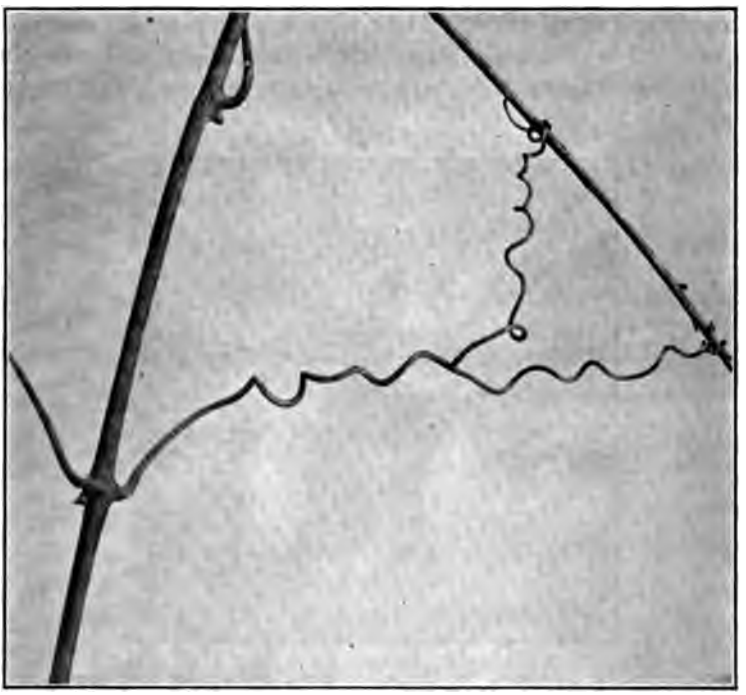


FIG. 60.—A tendril of the grape. Note how it pulls itself up to its support by twisting. Bring some tendrils into the laboratory and sketch them to impress upon your minds how this is done.

perennially and often kill the trees over which they grow. Many vines are annuals and grow as weeds or are cultivated in gardens. Vines are of many kinds and belong to many different families of plants. Many of them have taken up the climbing habit independently, therefore it is not surprising that they should climb by various methods. We will discuss four types: (1) scramblers, (2) twiners, (3) tendril climbers, (4) root climbers.

1. **Scramblers** are the poorest of climbers. They have no special climbing structures, are usually thorny, and grow in a profuse, sprawling mass. Examples are,—blackberries, dewberries, some kinds of asparagus, and the scrambler (rambler) rose.

2. **Twiners** are very good climbers. They wrap around their support in a spiral curve. These vines are very slender and grow rapidly. The following are examples: morning-glories, climbing beans, some honeysuckles, wild buckwheat, bindweed, and the hop vine.

FIG. 61.—Disc tendrils of the Virginia creeper. Roots are developed later.

3. **Tendril climbers** climb by modified leaves or stems. In the grape a branch which has lost most of the ordinary characteristics of branches coils around any small object which it touches. It then twists itself into a coiled spring and draws the vine up close to the support. Some twiners are very sensitive. Those of the star or bur cucumber (*Sicyos*) will respond to a pressure equal to one eighth of the smallest amount that can be perceived by the most sensitive part of the human skin.

In the pea, part of the leaf functions in the normal way, but the tips of the veins of the leaves are modified to curl around the support.

In the Virginia creeper, the tendrils terminate in flat discs which act as suckers. By this means it is able to climb up the bark of a tree or a brick wall. The gourd family (*Cucurbitaceæ*) including gourds, cucumbers, squashes, pumpkins, and melons comprises a well known group of tendril climbers.

4. **Root climbers** may be illustrated by the poison ivy, English ivy, and the trumpet creeper (*Techoma*). Many small roots grow out all along the stem and fasten themselves to the rough surface of the support.

FIG. 62.—The climbing roots of the Virginia creeper. On a field trip observe how they cling to the bark of trees and brick walls.

III. PROSTRATE STEMS are those that lie along the surface of the ground. These plants have apparently given up the struggle to ascend into the light and have become adapted to live in situations where this struggle is not necessary. It seems that they ignore the great prize that other plants strive for, but in losing this advantage they gain others. As they grow over the ground, roots are sent down from the joints in their stems, and thus they may spread rapidly. Many of their stems resist freezing in winter. They are not blown down by wind or easily eaten off by grazing animals. They conserve the food and energy used by other plants for extensive stem building, and being close to the ground, and having many roots, their water supply is more easily maintained. White clover, strawberries, portulaca, dooryard knotweed (*Polygonum*), and many kinds of grasses have prostrate stems. Plants with prostrate stems

are found growing on poor soil in abandoned fields, on sand beaches, along roadsides, on lawns, and in pastures. Many of them are persistent weeds, especially around dwellings and in barn yards.

IV. UNDERGROUND STEMS have completely abandoned the contest for sunlight and have become buried beneath the surface of the

FIG. 63.—The rhizome of the cat-tail. Note the long white roots and the two buds which are to produce the plants of the next season.

soil. Some of them, like the bracken fern, have delegated the work of elevating the leaf surface to the leaf-stem (*petiole*). Like the prostrate stems, the underground stems have apparently gained as much as they have lost by their peculiar habit of growth.

Underground stems may be classified, as rhizomes, tubers, corms, and bulbs. We have studied the *rhizome* of the goldenrod and noted that it served as a means of maintaining the life of the plant through the winter and to multiply the number of plants in the spring. Plants like the blue flag, cat-tail, and water lily have very fleshy rhizomes and store considerable food in them. This food is available for the rapid production of foliage the next spring.

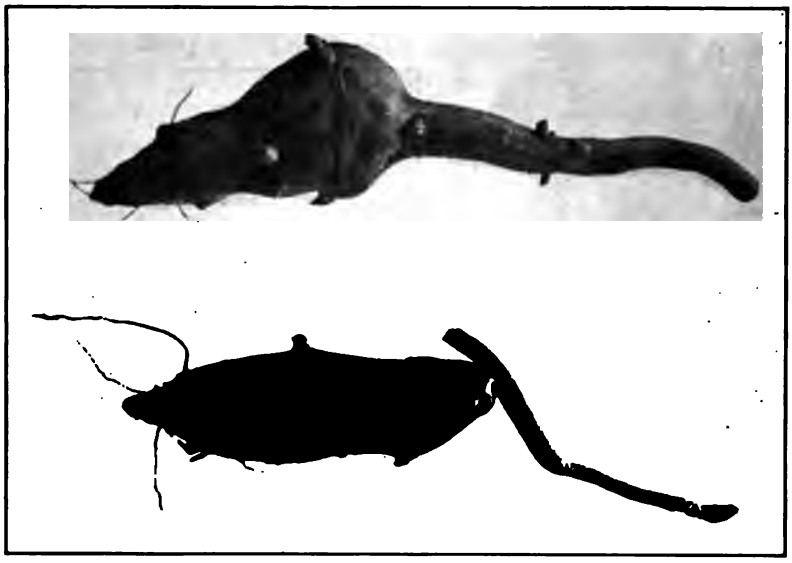


FIG. 64.—Two tubers of the artichoke. Note the eyes. They are buds, and the scales behind them are undeveloped leaves. The one above is terminal, the other is lateral. Sweet potatoes do not have eyes.

A tuber is a special kind of rhizome where the food is stored at the end of the stem rather than all along it. The Irish potato is our best known example. (Sweet potatoes are not tubers but are fleshy roots.)

The corm is a hard, compact stem-base. The gladiola and Jack-in-the-pulpit are good examples of this type of underground stem.

A bulb is really not a stem. It is composed of fleshy leaves clustered about a small stem. A bulb may be compared to a fleshy

bud or a cabbage, ready to grow the next spring with vigor. Corms, tubers, and fleshy roots are often incorrectly called bulbs. The following plants have bulbs: onion, lilies, tulips, and the daffodil.

Make a table listing the advantages and disadvantages of the four classes of stems and discuss it in class.

FIG. 65.

FIG. 66.

FIG. 65.—The corm of the cyclamen. This plant may be raised from seed and is a very beautiful flowering plant. Secure one for the laboratory.

FIG. 66.—The bulb of the onion. Cut some onions across and longitudinally and draw sketches of the surfaces exposed.

Project.—Make a collection of all of the types of stems mentioned in this study and preserve them properly in a museum case.

Laboratory Work.—Secure specimens of rhizomes, bulbs, corms, and tubers. Plant them in flower pots and appoint committees to care for them during the winter. They will add cheer and beauty to the department

II. FORESTRY

How is tree life related to human life?

Forestry is the business and science of profitably maintaining tree life. The chief forest industry is lumbering. Forest trees may be classed as *evergreen*,—those that usually have needle-like leaves, bear cones, and remain green throughout the winter; and *deciduous*,—those that have broad leaves which are shed in the fall. More than three-quarters of our timber supply is furnished by the *coniferous trees* (cone bearers). They are all classed as *soft woods* although some of them are quite hard and strong. The broad leaved trees are either hard or soft according to the weight and strength of their wood. Oak, maple, hickory, and walnut are classed as hard woods and are now very high priced. Basswood, sycamore, tulip tree, and poplar are soft wood trees. Woods,—like birch, elm, ash, and gum are intermediate in grade and are being drawn upon to take the place of the rapidly disappearing hard woods.

While lumbering is the chief interest of forestry, it is by no means the only one. Some land soon becomes worthless when the forests are removed. Water is retained by the leaf mold on the floor of the forest, and the shade prevents its evaporation. As long as the trees remain, the land is productive and the soil remains fertile. When this protection is gone, the soil may be washed away and the bed rock or infertile subsoil exposed This is not apt to occur on rich, level land but if the subsoil is loose sand, as is the case along much of the eastern shore of Lake Michigan, sand dunes develop and the land becomes worthless; or, if it is hilly, gulleys may develop.

When the forests are gone the rain water which they formerly retained rushes down the hill sides carrying with it the fertile soil. It carves out gulleys, floods streams, inundates lowlands, and fills navigable rivers with silt. All land that will support tree life and that is not suitable for agriculture should be planted with trees.

Values are not all measured in gold. Trees are valuable for their beauty and shade. The woods, groves, and solitary trees of a landscape add a necessary, artistic value that can not be reduced to mathematics. What would our city parks and streets be without their trees and the birds that live in them?

Aside from furnishing lumber, shade, and beauty trees have many economic values. If time permits some of the following topics may be assigned and reported on in class: relation of trees to avalanches and land slides, wind breaks, wild fruits and nuts, maple sirup, rosin, turpentine, camphor, quinine, rubber, creosote, cinnamon, cork.

Under natural conditions trees maintain themselves. Their most common method of reproduction and distribution is by seeds.

FIG. 67.—Winged fruits of the basswood. The fruits are borne in clusters and are attached to a bract which enables the wind to carry them away. They often hang on the tree until after Christmas, and are seldom detached except when a strong wind is blowing.

The seeds of pines, maples, ashes, and elms have "wings" and sail in the wind. Those of cherries, oaks and hickories are carried by birds and squirrels. Cottonwoods and willows send up sprouts from their roots. The chestnut, ash, and oak send up sprouts from their cut stumps. Woodlands are more rapidly renewed by sprouting than by growing from seed. Such growths are called *coppice*

woodlands. In many localities nature does not replenish the tree growth and artificial seeding or transplanting must be resorted to.

FIG. 68.—Coppice sprouts of the basswood growing around a small stump. Can they all survive and produce trees?

How to Transplant a Tree.—Trees should be dug up carefully with their roots in the fall or early spring and replanted while the ground is moist and the weather cool. The hole should be larger

than the root-mass and the soil used for filling the hole should be rich and finely divided. If clay soil is used and water is poured into the hole, the soil will pack and prevent good root growth. Before planting, the tree should be pruned so that the top is no more extensive than the root system. If the first summer is dry the tree should be watered and perhaps more extensively pruned.

In the forest where trees grow close together the lower branches are shaded and die before attaining large size. This is called *self pruning*. It is not profitable or necessary to prune trees in forestry projects; but park, shade, and fruit trees often require

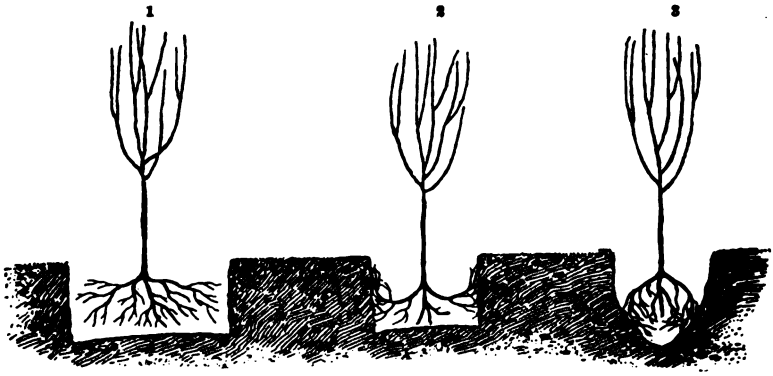


FIG. 69.—The hole in Fig. 1 is properly dug. Criticise the other two. (*U. S. Dept. of Agriculture.*)

trimming to alter their shape, or *pruning* to remove dead wood or thin the branches.

In removing a large limb a cut should be made from below first. If this is not done it may peel the bark down the side of the tree when it falls. When the limb is off the cut surface should slope so as to drain off the rain water and should be painted to keep out the spores of fungus diseases. If the limb is cut close to the tree it will heal over more quickly than it will if a stub is left.

The need of preserving our forests is great. In former years the forests were a hinderance to agriculture. The pioneers destroyed the trees to make room for crops but now the forests are so depleted in the populous parts of the country that an effort is being made to

FIG. 70.—The beauty of this hickory tree has been spoiled by close trimming. Do not destroy the natural habit of growth in trimming trees.

FIG. 71.—How to remove a large limb from a tree. Explain why the limb should be cut first at *a–b*, then at *c–d*. (*U. S. Dept. of Agriculture.*)

reestablish, on land not suited to agriculture, the forest that has disappeared. The Federal Government has set aside over 167,000,000 acres of forest land in the western states, and the State of New York has established the Adirondack Park of 1,500,000 acres in the interest of forest conservation.

The business of forestry is in its infancy, and the profits to be expected are uncertain. Furthermore, the investor in forest projects must wait several years to realize a profit. It is probably not advisable to plant trees for lumber on good agricultural land, but on land that is now idle trees may be planted or encouraged to grow, and some day a handsome return will be realized. Then, if the trees are properly cut and cared for, the supply of lumber will be continuous and permanent.

The kind of trees to plant depends upon the climate, the condition of the land, and the use to be made of the product. Spruce and white pine have been planted in the East. In the South the various forms of eucalyptus from Australia, especially *Eucalyptus globulus*, give great promise because of their rapid growth.

Tree improvement should be a profitable business for the experimental breeder. The Norway spruce and the soft maple have been improved as shade trees, but little has been done as yet to improve our trees used for lumber. Burbank has produced a hybrid between the English and American black walnuts which shows great promise in the rapidity of its growth and the quality of its wood.

In the past, trees have been so plentiful that little attention has been paid to conservative methods of lumbering. Trees should be cut close to the ground so as to avoid waste in the stump. The tops should be made into fence posts and firewood. Trees should stand close together to make tall, clean trunks, but if they are too thick they will not grow rapidly, in which case the small ones may be removed and used as fence posts. When a tree is felled it should not be allowed to break down younger and promising trees. Much valuable timber has been destroyed by forest fires which are usually preventable. When fire passes through a forest everything is destroyed. Even the soil is burned out leaving the hillsides to be gullied by the rain water.

Cattle and sheep raising do not go well with forestry. Grazing

animals eat off the seedling trees and soon the old trees alone remain. When they are cut there are no saplings to take their place, and the forest is destroyed. Sheep, especially, eat off the vegetation on the floor of the forest and cut up the soil with their sharp hoofs. This starts erosion, and soon the hillsides are gullied and the surface soil washed away.

Field Trips.—Learn to recognize the common trees. Find out something about their life history and habits. What animals and birds inhabit them? How are their seeds distributed? Collect samples of their leaves, fruits, and stems.

Excursions.—Observe the relation of trees to erosion.

Learn to recognize the common woods used in buildings and making furniture.

Reports.—What is veneer, and how is it made?

How rapidly has the price of lumber advanced in the past fifty years?

Where are the present lumber districts of the United States? What kinds of lumber do they contain? How much is left?

12. THE STRUCTURE OF LEAVES

Of what do leaves consist?

We are now about to take up the study of the most interesting part of the plant. In the spring, it is the return of the green leaves of countless forms and sizes, coming forth by the millions, almost in a day, that tempts the school boy from his books and calls him out into the woods and fields. Nature is at her best when the hills and meadows are clothed with the fresh, green leaves of spring.

The variety of leaves is so great that they almost defy description. We can best approach the subject by examining a few common forms. The geranium leaf is attached to the plant stalk by a long stem called the *petiole*. The leaf proper is called the *blade*. In the blade the petiole is divided into many branches which form the skeleton of the leaf. These branches are called *veins*. In the geranium leaf there are many of about the same size. In the bean leaf the divided petiole is continued as a main vein or *midrib* through each of the three parts of the leaf and branches are given off from the sides. Leaves like those of the nasturtium, castor oil plant, and geranium are said to be *palmate veined*, because the veins run out as do the fingers from the

palm of the hand. Leaves like those of the bean, apple, or fuchsia are said to be *pinnate veined*, because their veins run out from a midrib like the barbs of a feather. Leaves of such plants as grass and corn have a midrib, but the smaller ones run parallel to it. Such leaves are said to be *parallel veined*. Pinnate and palmate veined leaves are said to be *net veined* because the small veins form a network.

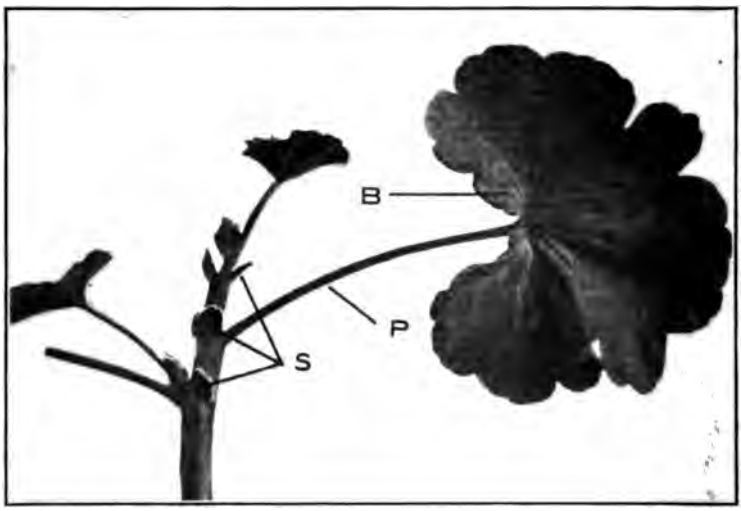


FIG. 72.—Geranium leaf, photographed to show the parts of a typical leaf. *B*, blade; *P*, petiole; *S*, stipules. Note the bud growing in the axil of the leaf just below the one which is labeled. This is the usual position for buds. Where else are they found in other plants? See also Fig. 76.

If we examine the leaf of the pea, rose, or locust tree we shall find that the side branches have become midribs of secondary leaves called *leaflets* which are arranged along the sides of the midrib. Such leaves are said to be *compound*. We may have *compound pinnate* or *compound palmate* leaves. Those just mentioned are compound pinnate. The horse chestnut leaf is a good example of a compound palmate leaf. Compound leaves like those of the bean and clover are said to be *trifoliate*.

Attached to the base of the petiole of the leaf of the pea and geranium are two large, leafy structures called *stipules*. They are

not found on all leaves. Examine a collection of various kinds of leaves in class and compare them with the types mentioned above.

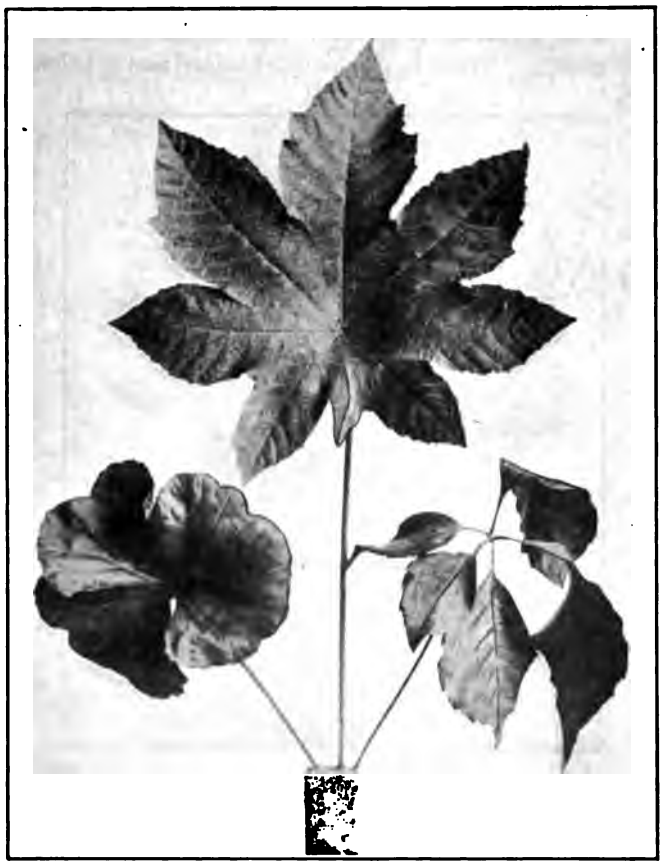


FIG. 73.—Three types of palmately veined leaves. 1, geranium—simple palmate; 2, castor-oil plant—lobed palmate; 3, Virginia creeper—compound palmate.

Do you find any without a petiole? Leaves which have no petiole are said to be *sessile*.

All leaves may be arranged in two groups: those with parallel

veins and those with *net veins.* In the study of stems we defined two types: the *endogenous* and *exogenous* stems; and we said that plants having endogenous stems belonged to the class MONOCOTYLEDONEÆ, and those having exogenous stems to the class DICOTYLEDONEÆ. Leaf structure is another characteristic which varies in these two groups. Those having parallel veined leaves belong to the

FIG. 74.—Pinnately veined leaves from the vegetable garden. 1, beet—simple pinnate; 2, radish—lobed pinnate; 3, parsnip—compound pinnate; 4, carrot—doubly compound pinnate.

class MONOCOTYLEDONEÆ, and those having net veined leaves belong to the class DICOTYLEDONEÆ.

Leaves are arranged on the plant stem in two ways. Those arranged as in the horse chestnut and elder are *opposite.* Those arranged as in the geranium are *alternate.* In the opposite class the leaves are arranged in pairs. Each leaf having its duplicate

on the opposite side of the stem. In the alternate type they are single and ascend the stem in a spiral so that they do not set directly above each other.

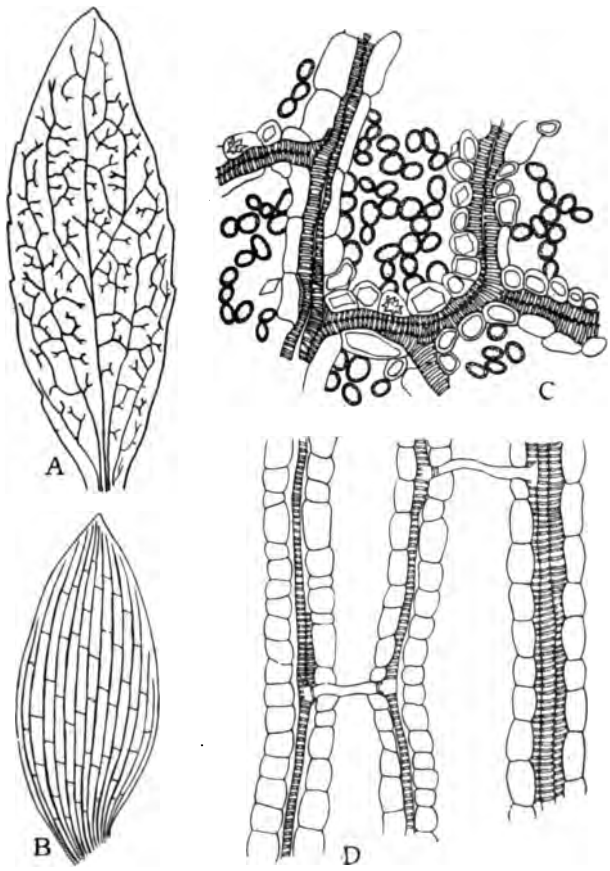


FIG. 75.—Diagrams of net veining in a dicotyledon leaf (*A* and *C*); diagrams of parallel veining in a leaf of a monocotyledon (*B* and *D*). (*From Stevens.*)

Leaves seek the light, and it is the business of the petiole to place the leaf blade in the most favorable light conditions. But there is still another important function for the petiole to perform. The leaf must be nourished, and some of the products of its activity must

be returned to the roots. The petiole is the means of communication between the leaf and the rest of the plant. It contains much fibro-vascular tissue through which the sap flows. Aside from serving

FIG. 76.—Compound leaf of the sweet pea. (*From Robbins.*)

as a skeleton for the support of the leaf blade, the veins serve as collecting and distributing channels throughout the leaf tissue.

The leaf blade is surrounded by a layer of flat, colorless cells. They constitute the epidermis and prevent the evaporation of mois-

ture, keep out dust and spores of parasitic plants, and being very tough, prevent mechanical injury.

In the epidermis there are openings surrounded by kidney or banana-shaped cells which are capable of changing their shape so as to open or close the slit between them. These openings are called

FIG. 77.—Opposite and alternate leaf arrangement. Apple at the left and forsythia at the right. Note the stipules at the bases of the leaf-stems of the apple shoot.

stomates (Gr. *stoma* = mouth). Gases pass in and out through the stomates. In the leaves of the water lily the stomates are found on the upper surface only. In erect leaves they are found on both surfaces, and in horizontal leaves they are mostly confined to the lower surface. Can you give reasons for this?

The green tissue between the upper and lower epidermis is the *mesophyll* (mĕzō-fĭl: Gr. *mesos* = middle + *phyllos* = leaf). The

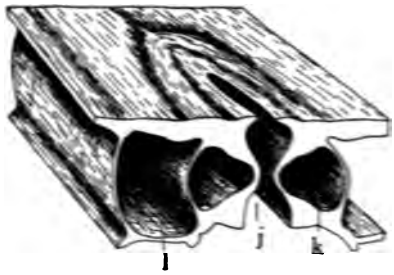


FIG. 78.—Sterogram of a stomate of a leaf. The heavy walled cells (*k*) bordering the slit (*j*) are the guard cells, surrounded by epidermal cells (*l*). (*From Stevens.*)

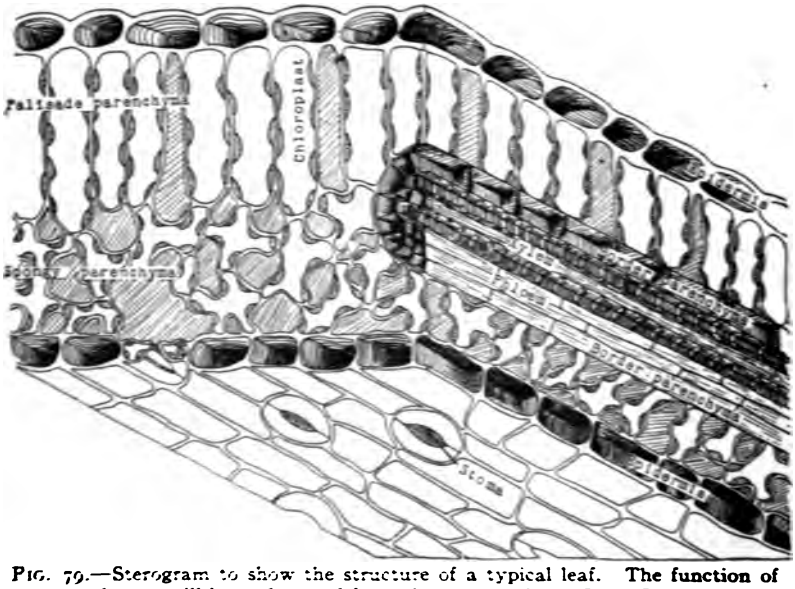


FIG. 79.—Sterogram to show the structure of a typical leaf. The function of each part will be understood from the next study. (*From Stevens.*)

palisade cells lie next to the upper epidermis. They are shaped like columns or palisades and are set close together. Next to the lower epidermis is the *spongy* or *parenchyma* (parent) tissue. It is soft and

composed of irregularly shaped cells set loosely together with air spaces between them called *intercellular* spaces. These spaces communicate with the stomates. We will take up the work of this green tissue in the next lesson.

The reading matter of this study has been shortened to allow for more illustrations. They should be carefully examined.

Field Trips.—Make collections of all of the kinds of leaves mentioned in this study. Draw some of them, press the perfect ones and put them, properly mounted, in a museum case.

Individual Project.—Can some one make a model of a cross section of a leaf? Use a mixture of salt and flour. It will dry hard and keep well. Mount it on a board and color it with water colors. When your museum case gets full invite the board of education in to see it, and ask them for another one.

13. THE WORK OF LEAVES

What work do leaves do?

We will discuss the work of leaves under four topics,—photosynthesis, assimilation, transpiration, and respiration.

PHOTOSYNTHESIS.—We have seen how the roots of plants take up water containing mineral salt and pass this material up to the parts above ground. This is the source of part of the food of plants. The greater part of the food of plants, however, comes from the air.

In the cells of the palisade and spongy tissue of the leaf there are small green bodies called *chloroplasts* (Gr. *chloros* = green + *plastos* = molded). They can be seen in most any green, leaf tissue by the aid of the high power microscope. These bodies contain a green substance called *chlorophyll* (Gr. *chloros* = green + *phyllon* = leaf). This material contains the *ferrous* salts of iron linked with the protoplasm of the cell. It is insoluble in water but soluble in alcohol, and is capable of absorbing the energy of light and transforming it into chemical energy.

Excepting nervous tissue, chlorophyll is perhaps the most wonderful substance in living things. Without it all life on this earth would disappear. All plant food is first organized in this material; and since the animal kingdom is dependent on the plant kingdom for food, the kind of life we have on earth would perish for lack of nourishment.

Carbon dioxide (CO_2) gas exists in the air in very small quantity. It is taken into the leaf through the stomates, absorbed by the green cells, and broken up into carbon and oxygen. Then it is combined with hydrogen and oxygen which are obtained by reducing the molecules of water (H_2O) to the two gases of which they are composed. These three chemical elements,—hydrogen, oxygen, and carbon, are then combined to form molecules of starch. The simplest formula for starch is $C_6H_{10}O_5$. We may express the reaction thus: $6CO_2 + 5H_2O \rightarrow C_6H_{10}O_5 + 6O_2$. You will see from this

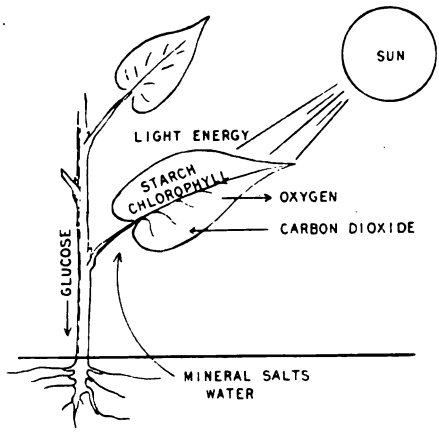


FIG. 80.—Diagram of photosynthesis. Study this diagram carefully and understand where the oxygen, carbon dioxide, and water come from and where they go. Note that the carbon on which the plant depends so much comes from the air and that a comparatively small amount of salt comes from the soil.

equation that as much oxygen as is contributed by the carbon dioxide is released to the air, and only five atoms (or their equivalent) contributed by the water go into the formation of the starch. Water contains twice as many atoms of hydrogen as of oxygen, and so does starch. Hence, starch is called a *carbohydrate* (carbon + water). Sugars and cellulose are other plant substances which are carbohydrates. They always contain two atoms of hydrogen for every atom of oxygen. Recall what was learned in regard to this from the introductory chapter.

Most chemical actions are attended by positive energy manifestations, *i.e.*, they give off light, heat, or electricity while they are going on. Such reactions are said to be *exothermic* which means that they give off heat. In the formation of starch, energy is absorbed. Such reactions are said to be *endothermic*. The energy which is absorbed in the formation of starch is the energy of sunlight transformed into chemical energy. Hence, unless the chloroplasts are receiving light they are incapable of making starch. The process of making starch from carbon dioxide and water, in the green tissue of the plant, under the influence of sunlight, is called *photosynthesis* (Gr. *phos* = light + *synthesis* = composition).

ASSIMILATION.—Under this heading we will discuss those changes by which the plant absorbs food and makes it a part of itself. The change from starch to sugar or cellulose is relatively simple since sugar and cellulose are carbohydrates having a chemical composition similar to that of starch. The form of sugar most commonly found in plants is *glucose*. It is made from starch in the chemical laboratory and sold as "corn sirup." Corn starch is boiled with sulphuric acid and the following reaction takes place:

$$\underset{\text{starch}}{C_6H_{10}O_5} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{glucose}}{C_6H_{12}O_6}$$

Starch, as it exists in plants, is not soluble in cold water. Insoluble matter is not conveyed through plant tissue; and, hence, if it is to be moved from the leaf to the stem or root, it must be changed to glucose which is soluble. In the sweet potato starch may be made in the leaf, changed to glucose and deposited in the root, where it is again changed to starch and stored until spring, when it is once more changed to glucose and used in building up the tissues of the young plant. Thus, we see that assimilation is not confined to the root. It may occur in any part of the plant.

Carbohydrates, *organic oils*, and *protein* constitute the three classes of plant foods and tissues. The *oils* contain carbon, hydrogen, and oxygen as do the carbohydrates and are made from them in the green tissue of the leaf and in other places in the plant.

Proteins contain carbon, hydrogen, and oxygen as do the carbohydrates and fats, and nitrogen and sulphur in addition. They

often contain other mineral matter, such as potassium, phosphorous, and iron. Proteins can not be formed unless these elements from the soil are present. We are now able to understand why the soil is so essential to plant life. The living tissue of the plant, as distinguished from the wood and stored food, is composed of proteins organized into living protoplasm. Without the salts from the soil this protoplasm can not be formed.

The food of plants meets one of three fates: it may be ***built into new tissue; stored*** away in leaves, stems, roots, or seeds for future use;

FIG. 81.—Guttation drops on a tomato leaf. Try to obtain such drops by placing a succulent plant under a bell jar for a few hours.

or it may be *oxidized* and used to release energy for the maintainance of the plant. In using the term "storage" we should not get the idea that the plant is in any way conscious of the future use to be made of this food. Dr. J. G. Coulter has suggested that the term *accumulation* be used instead of *storage*.

TRANSPIRATION.—We have already learned that the mineral food of the plant comes from the soil, is taken up in solution with water by the root hairs, and passed up to the leaves. This process

is constantly going on. The question which now arises is, "What becomes of all this water?" Much of it is used and retained in the plant, but there is an oversupply. The excess passes into the intercellular spaces and then out through the stomates in the form of water vapor. If the air is very moist it may not get out in this way fast enough. Under such circumstances the water passes out through *water pores*, which are modified stomates, and collects in

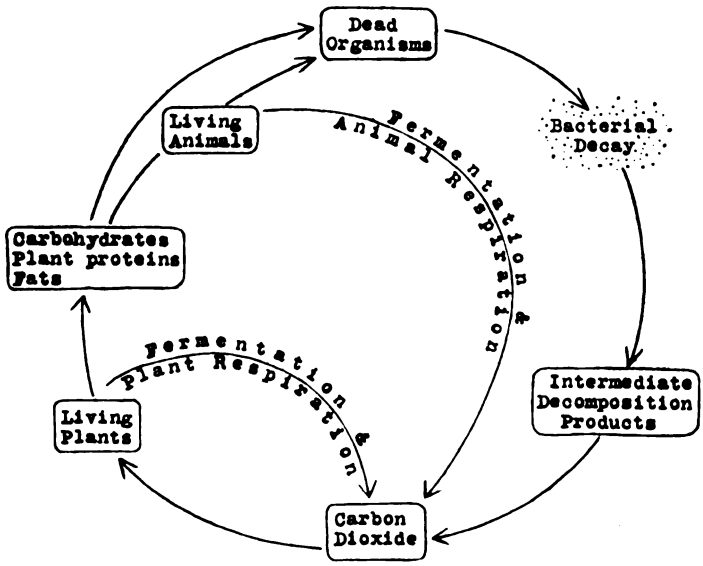


FIG. 82.—The carbon cycle showing how carbon dioxide of the air is taken up by living plants and the ways in which it is returned to the air. (*From Gager.*)

drops on the edges of the leaves. This method of getting rid of excess water is called *guttation*.

In transpiration much mineral matter which can not be assimilated is unavoidably brought to the leaves. Silica and lime accumulate in this way in considerable quantity. Dead leaves are heavily charged with mineral matter. Fall leaves are often bright red and yellow. This is partly due to accumulated mineral matter which they contain but mostly to the iron in the dead chlorophyll. The

ferric salts of iron are red. Frost may hasten the appearance of color but does not cause it.

RESPIRATION.—It is common knowledge that animals breathe or respire. It is not so well known that respiration takes place in plants also. The gases which pass in and out do so by *diffusion,—i.e.*, a free mingling of the gases inside the leaf with those outside due to the natural movement of the molecules of the gas. In photosynthesis we have seen how carbon dioxide is absorbed and oxygen is given off. In respiration this interchange is reversed. Oxygen is absorbed and carbon dioxide is given off. Although the plant has no nervous or muscular system, it is an active, living thing. It grows, circulates sap, and responds to heat, light, gravity, and moisture conditions. These activities require energy for their performance. This energy is obtained by oxidation of food substances and results in the liberation of water and carbon dioxide gas. The interchange of gases through the stomates is shown in the table below.

Process	Gases absorbed	Gases liberated
Photosynthesis	carbon dioxide	oxygen
Respiration	oxygen	carbon dioxide and water vapor
Transpiration	none	water vapor

Laboratory Projects.—Place a plant in total darkness and note how long it takes to lose its green color. Try more than one species. Do they all respond the same?

Obtain guttation drops by placing a succulent plant under a bell jar.

Seal a plant in a flower pot by covering the pot with rubber sheeting or paraffin so that all water must escape through the leaves. Keep a record of the loss in weight day by day.

Teacher's Demonstration.—Seal a plant in a glass jar or under a bell jar. Provide a dish of alkaline pyrogallic acid solution to absorb all of the oxygen. How long does the plant live without oxygen? Are all plants affected the same?

Committee Project.—Collect some colored leaves in the fall. Dip them in melted rosin to give them a gloss, and display them as objects of beauty.

Food Problems of Animals

14. THE FOOD OF ANIMALS

How are animals adapted to their food supply?

The methods of obtaining food constitute the most constant difference between plants and animals. We have seen how plants take in mineral salts and water through their roots by osmosis, and how they absorb carbon dioxide from the air and organize these three substances,—salt, water, and carbon dioxide, into food. This, of course, can be done only by green plants.

The fungus plants, such as bacteria, molds, and mushrooms, are not green, and, hence, absorb no carbon dioxide for starch making. Therefore, they are compelled to live where they can absorb carbon, hydrogen, and oxygen in an organized form,—*i.e.*, in the form of carbohydrate, fat, or protein. These foods are taken up by osmosis much as green plants take up salt. *The essential thing about plants is that they do not take into their bodies organized, solid food to be digested.*

Animals do not have chlorophyll and, hence, can not organize their food from mineral salt, water, and carbon dioxide; nor do they absorb water and minerals as do plants. Furthermore, animals are not capable of absorbing the energy of light and using it in food building. In other words, *animals can not live on air and water as can plants.*

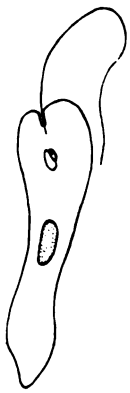


Fig. 83.—The euglena has the rare distinction of being classified both as an animal and a plant.

Euglena.—You may find floating on the surface of ponds in summer a small, green creature called a plant by botanists and an animal by zoologists, because it feeds like a plant and also like an animal. It belongs to the genus *Euglena* and is composed of a single cell. It can contract like a ball or stretch out like a rod. At one end is a long lash which vibrates in the water and pulls the euglena along. Near the base of the lash is a gullet through which small particles of food,—such as bacteria are taken in. These particles are surrounded by a fluid which digests them, and they

become a part of the euglena. Indigestible matter is cast out through the cell wall. Some forms of euglena are not known to take in any solid food at all but live like a plant by photosynthesis.

FIG. 84.—The vase sponge swims during its larval life but remains attached at the base of its stalk throughout its adult life.

Others have no chlorophyll and live like animals by digesting food. Evolutionists tell us that it is probable that a creature something like euglena was the ancestor of both the plant and animal kingdoms.

Animals may be divided into two groups according to their method of obtaining food,—those that are *attached* and those that are *free* to move about. Those that are attached,—such as sponges, corals, barnacles, oysters, some worms, and the sea lily are all *aquatic* (Lat. *aqua* = water) and have their food brought to them by water currents. Their food consists of small plants and animals which float in the water. There is much more of this kind of food in the water than most people think there is. These animals are all simple in structure and, with some doubtful exceptions, belong to the *invertebrates* (animals without a backbone).

The animals which are free to go in search of food are more highly organized. Their senses are usually well developed. They may swim in the water, burrow in the ground, walk, crawl, jump, or run over the earth, or fly in the air. Their food is of two kinds,—animal and vegetable. Those that eat plants are said to be *herbivorous* (Lat. *herba* = plant + *vorare* = to devour). Those that eat other animals are said to be *carnivorous* (Lat. *carnis* = flesh + *vorare*). Some eat both kinds of food, they are said to be *omnivorous* (Lat. *omnis* = all + *vorare*). Make a list of animals and assign them to one of these three classes. Discuss doubtful cases in class.

Adaptation.—Each animal is remarkably adapted to obtain its particular kind of food. The teeth of horses and cows are adapted for cutting off grass and chewing it thoroughly. Cattle chew their food the second time. This is called "chewing the cud." Of what advantage is this? Rabbits are preyed upon by foxes and other carnivorous creatures. The wonderful ability of the rabbit to hide and run is equaled by the cunning and speed of the fox which catches it. Make a list of the animals which are eaten by the fox. What are their various methods of escape? Make another of the animals which prey upon the rabbit. Compare their methods of capturing it. Compare and discuss these lists in class. We will have more to say later about the intense struggle for existence among living things.

The foods that are taken into the bodies of animals are reorganized and built into the animal's body by growth or repair processes, stored for future use usually in the form of fat, or are oxidized for the release of energy. Animals are more active than plants and

use most of their food in oxidization. The warm blooded animals (birds and mammals) release a large amount of energy in the form

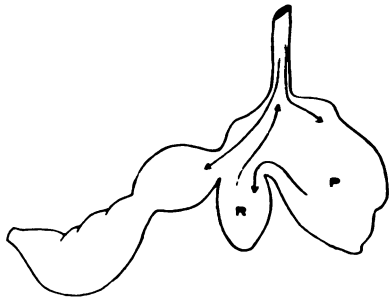


FIG. 85.—Diagram of the stomach of a cud chewing animal. The pauch and reticulum—*P* and *R*— are outgrowths of the esophagus. The cud is formed in the reticulum and sent back to the mouth to be chewed again before it passes into the stomach proper which is usually divided into two compartments. What advantage has the cow over the horse in feeding?

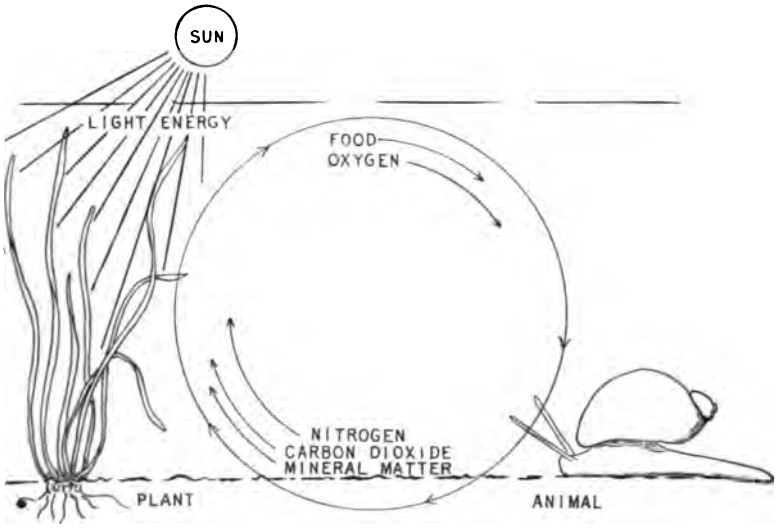


FIG. 86.—Diagram of the food cycle in an aquarium.

of heat to keep the body warm. They are much more active than the cold blooded forms and consume large quantities of food.

The Food Cycle.—When carbohydrate foods are oxidized in the bodies of animals they are changed into carbon dioxide and water thus:

$$C_6H_{12}O_6 + O_2 \rightarrow 6CO_2 + 6H_2O$$
Glucose + oxygen → carbon dioxide + water

Thus the animal reduces food to the elements from which it was made by the plant. *Plants are constantly building up food matter out of simple substances and animals are constantly breaking it down into simple substances again.* These two processes are about equal on the earth and constitute what is known as the *food cycle.*

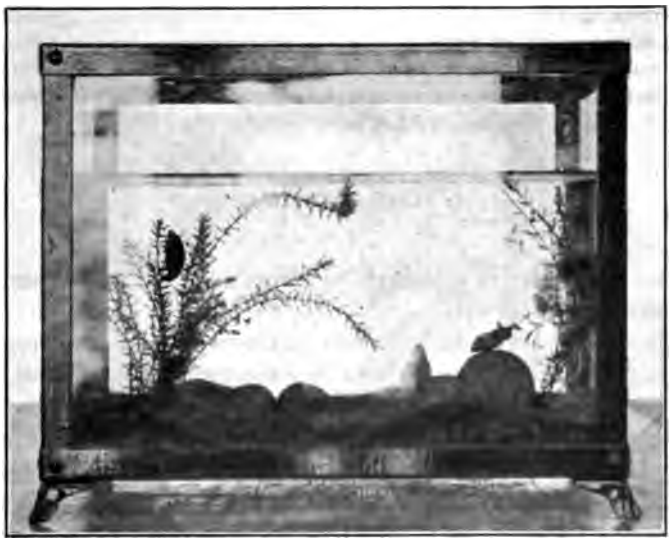


FIG. 87.—A balanced aquarium. Note that it is not overcrowded. If the students have not already made a few aquaria they should do so at this time. Appoint certain individuals to watch them.

The balanced aquarium illustrates this principle. If water animals, such as goldfish, pollywogs, snails and protozoans are placed in a jar of water with water plants, such as algæ, duck weed and ditch moss, and the heat and light conditions are favorable, they will live together indefinitely. The animals furnish the plants with elementary food substances, and the plants are eaten by the animals.

Animal respiration and plant photosynthesis balance one another. In making a balanced aquarium one should avoid putting in too many animals. They may eat all the plant food available and starve. A permanent pond illustrates this same principle on a large scale.

Field Trip.—If a pond is near the school an excursion should be made to it at this time. Remove a quantity of the vegetation to the laboratory, and there make a study of the animals found on it. Make a balanced aquarium and keep it the rest of the year. Use *Life of Inland Waters* by Needham and Lloyd, Comstock Pub. Co., for identification of the forms found.

Boy's Project.—Can someone secure skulls of a carnivorous animal and an herbivorous animal and demonstrate the differences in the teeth to the class?

Report.—Appoint someone to secure illustrations and prepare a topic on *Insectivorous Plants*. The sundew, Venus' fly-trap, or a pitcher plant will serve.

Project.—Collect some euglena and place them in pure water in a moderate amount of light. How long do they live? What do they live on?

15. FOOD AND ITS USES

What is food?

We will discuss five classes of foods,—carbohydrates, fats and oils, proteins, salts, and water.

CARBOHYDRATES.—We have seen that carbohydrates are produced by protosynthesis in plants where they are used as the basis for making other foods,—such as fats and proteins, built into woody and bark tissues, oxidized for the release of energy, or stored for future use. They are usually stored in the form of starch or glucose. Maple sap, sugar cane, and sugar beets contain large quantities of the sugar we use on the table. It is called *saccharose* ($C_{12}H_{22}O_{11}$).

These foods may be stored in most any part of the plant. When they are stored in sufficient quantity and in a palatable form the plant may be used as food for man. The following domestic plants contain food stored in the root, stem, leaf, fruit, or seed. Arrange them in a table showing where the food is stored in each case. Turnip, cabbage, beet, celery, wheat, kohlrabi, oats, rhubarb, watermelon, radish, sorgum, strawberry, cocoanut, banana, lettuce, onion, potato, sweet potato, carrot, corn, walnut, tomato, apple. After correction, place the table on the blackboard.

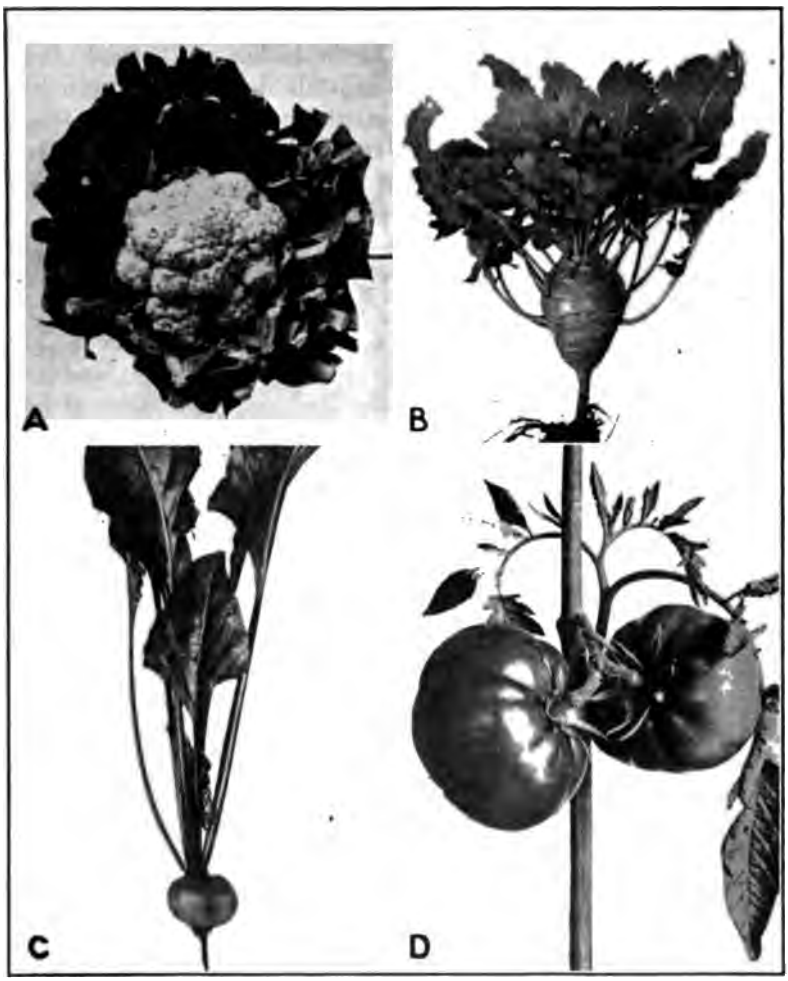


FIG. 88.—Plants which are used as food. *A*, the *flower* of cauliflower. *B*, *stem* of kohl rabi. *C*, the *root* and *leaf* of the beet. *D*, the *fruit* of the tomato are examples of parts of plants which are relished by man.

In animals carbohydrates are found in the system in the form of glucose or *glycogen*. Glycogen is a substance similar to starch but soluble in water and found only in the bodies of animals. It is sometimes called animal starch. Animals do not store carbohydrates except temporarily. They use them for building other foods and in oxidation for the release of energy. A sugar similar to cane sugar, called *lactose* ($C_{12}H_{22}O_{11}$), is found in considerable quantity in milk and is often called milk sugar.

FATS AND OILS are formed by both plants and animals, from carbohydrates and probably from proteins also. In plants they are stored largely in seeds but may occur in any part of the plant. Corn oil, cotton seed oil, linseed oil, olive oil, and castor oil are familiar plant oils. Butter, tallow whale oil, cod liver oil, and lard are animal fats. We will discuss the chemical composition of fats in the study on digestion.

In animals, food is usually stored in the form of fat. When so stored it may serve to retain the heat of the body. This is because fat is a poor conductor of heat. The body of the whale is protected from the arctic cold by thick layers of fat. Women are usually better protected by fat than men and, hence, do not dress so warmly in winter.

PROTEINS are built up in plants, as has been explained, from carbohydrates and mineral salts. *Animals can not form proteins in this way.* They must get them from plants or other animals. They reorganize them and make them more or less complex but can not originate them. Proteins are very complex substances. In plants they occur in the green tissues, seeds, and all growing parts. In animals, proteins are used for building blood, muscles, tendons, and nervous tissue. The white of an egg will serve as an example of nearly pure protein.

Pure proteins are composed of *amino acids*. These acids all contain at least one atom of nitrogen linked with two atoms of hydrogen. This group of three atoms (NH_2) is called the *amino group* and is always present in proteins. Through this group the amino acids are linked together to form proteins. One of the simplest amino acids is *glycocoll* ($C_2H_5O_2N$). Another one called *cystine* ($C_6H_{12}O_4N_2S_2$) contains sulphur.

The actual structure of the protein molecule is still unknown, and we have, as yet, no means by which its molecular weight can be determined. The simplest formula calculated for oxhæmoglobin, found in the blood, is $C_{658}H_{1181}N_{207}S_2FeO$. This serves to show the extreme complexity of this class of substances. If the above formula is correct, how many atoms are there in a molecule of oxhæmoglobin? When proteins are digested they take up water and break up into simpler proteins which are constantly more and more soluble

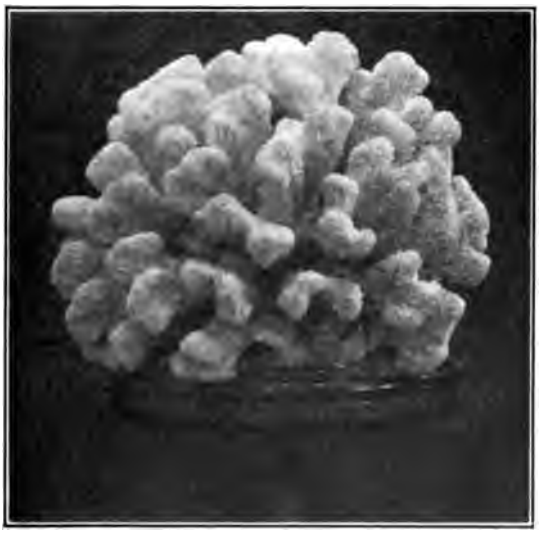


FIG. 89.—The skeleton of a coral which is built up by the deposition of lime salts.

in water and if the process goes to completion amino acids are left. Some other substances, such as carbon dioxide and ammonia may be formed also. Therefore, we are justified in concluding that amino acids form the basis of protein molecules.

Carbohydrates, fats, and mineral matter are not looked upon as being alive; nor is all protein material. The white of an egg and the casein of milk, for instance, are not alive; but *all living matter is composed of protein.* It always has water in it and the other foods are usually present, but they can not be said to be alive unless they are chemically linked with the molecule of living protein substance.

MINERAL FOODS, as has been pointed out, are more available to plants than to animals. Some plants use silica for building skeletons, but most rigid tissue in plants is carbohydrate material. Animals commonly build their skeletons of lime and phosphorous compounds. Corals, clams, snails, and crayfish use much lime in building up their skeletons. The vertebrate animals have an internal skeleton composed largely of lime carbonate and lime phosphate.

WATER is the most universal of all foods. It is present in all food and living tissue. It is the medium of transportation in the

	WATER	PROTEIN	STARCH	SUGAR	FAT	SALTS
Bread	37	8	47	3	1	2
Wheat flour	15	11	66	4.2	2	1.7
Oatmeal	15	12.6	58	5.4	5.6	3
Rice	13	6	79	0.4	0.7	0.5
Peas	15	23	55	2	2	2
Potatoes	75	2	18	3	0.2	0.7
Milk	86	4	—	5	4	0.8
Cheese	37	33	—	—	24	5
Lean beef	72	19	—	—	3	1
Fat beef	51	14	—	—	29	1
Mutton	72	18	—	—	5	1
Veal	63	16	—	—	16	1
White fish	78	18	—	—	3	1
Salmon	77	16	—	—	5.5	1.5
Egg	74	14	—	—	10.5	1.5
Butter	15	—	—	—	83	3

FIG. 90.—The above table is taken from *The Human Mechanism*, by Hough and Sedgwick. A well balanced meal should contain some foods of the types illustrated by both those at the top and bottom of the table.

fibrovascular tissue of plants and the blood system of animals. When the temperature gets so low that water freezes plants die or go into a state of rest and animals become inactive, die, migrate, or have some means of keeping warm. If the earth should become cold and all the water on it freeze, life would be impossible. We know that life does not exist on the moon because there is no water there.

RELATIVE VALUE OF FOODS.—A common method of estimating the value of a food to the body is to measure the quantity of heat

a unit weight of it will give off when it is burned. This method determines the amount of energy it releases when oxidized. It does not determine its value as a tissue builder except by inference from its value when burned.

Calorimetry.—A small quantity of the food is burned in a vessel called a *calorimeter*. The change in temperature is noted and from this the quantity of heat is determined. *Quantity* of heat is very, different from *temperature*. Temperature measures the *degree of heat* but quantity is the actual *amount of heat* energy possessed by the body. A cup full of water and a kettle full may be at the same temperature, but there is more heat energy in the kettle than in the cup, because there is more water there.

The unit of measure of quantity of heat is the *calorie*. *It is the amount of heat required to raise the temperature of one gram of water from zero to one degree centigrade.* In practice a *Great Calorie* is used. It is spelled with a capital C thus,—"Calorie," to distinguish it from the smaller measure and is equal to 1,000 small calories.

All foods have been tested in this way and their values recorded in tables. One gram of fat gives about 9.3 Calories; one gram of glucose, sugar, or protein about 4 Calories. Carbohydrates and proteins are of about the same value, and are less than one half as valuable as fat. In estimating foods in this way the digestibility of the food is not considered. This is a serious defect. For instance, a gram of glucose and a gram of sawdust have about the same caloric value, but sawdust is a very poor food because we can not digest it. It is, however, a good food for those animals which can digest it. Termites and many kinds of wood borers thrive on it. In spite of this handicap, the caloric method is of great importance in evaluating foods.

Is Alcohol a Food?

No, it is not. Its caloric value is high, and it is oxidized in the body in some way since it does not appear in quantity in the excretions after being taken into the body; but it disorganizes the system, deadens nervous activity, interferes with normal circulation, digestion, assimilation, secretion, and excretion. This makes it a poison, and a pioson can not be a food. Beers and wines, minus

their alcohol, contain some food matter, but most of the food of the grain or fruit is destroyed in fermentation.

Tea and Coffee Are Stimulants.—They quicken the nervous activity for a time. Stimulants are not foods, but the milk and sugar taken with these drinks are foods. Tobacco, opium, cocaine, and chloral are examples of *narcotics*. They blunt the senses when taken in small quantities, while in large quantity they produce sleep or death. *Three drops of pure nicotine will kill a man.* These substances are habit formers, *i.e.*, they so disorganize the nervous system that their presence is necessary to steady the nerves so that the individual may go about his daily tasks. The effects of opium and laudinum are well known. Have some passages read in class from *Confessions of an English Opium Eater* by De Quincey.

Laboratory Food Tests.—*Starch* may be tested for by boiling the food, cooling, and adding iodine solution. A blue color, disappearing when the solution is heated and reappearing when the solution is cooled indicates starch.

Glucose may be detected by boiling the material in Fehling's solution. An orange color indicates glucose.

Carbohydrates usually turn black when they are covered with strong sulphuric acid.

Oils or **fats** may be tested for by digesting with ether and evaporating. The oils and fats will be dissolved out by the ether and left after evaporating their solvent. If they are abundant they may leave a clear spot on thin paper when the food is applied to it.

Proteins turn yellow in the presence of strong nitric acid. This color is intensified if ammonium hydroxide is added.

Free salts may be detected by digesting with water and then evaporating the water. They will be left as crystals.

Water may be detected even in very small quantities by placing the food in a test tube and holding it over a flame so that the upper part of the tube is not heated. The water will collect as drops on the inside of the tube.

The above tests may be assigned to committees and in this manner brought before the class. If laboratory facilities are adequate, each student may make the tests.

16. DIGESTION

How is food digested and why?

Digestion is the preparation of food for absorption. The food of plants exists in the soil or air in a soluble condition and digestion is not necessary. However, the root hairs of plants secrete acids

which help to render the solid food elements soluble. This is digestion in spite of the fact that it occurs outside of the body of the plant.

Some plants,—such as the Venus fly-trap, pitcher plants, and sundew catch insects and spiders in their leaves and digest them. These plants feed like animals and are notorious exceptions in plant life. They usually grow in poor soil and have acquired the habit of using animal food to compensate for the scarcity of plant food.

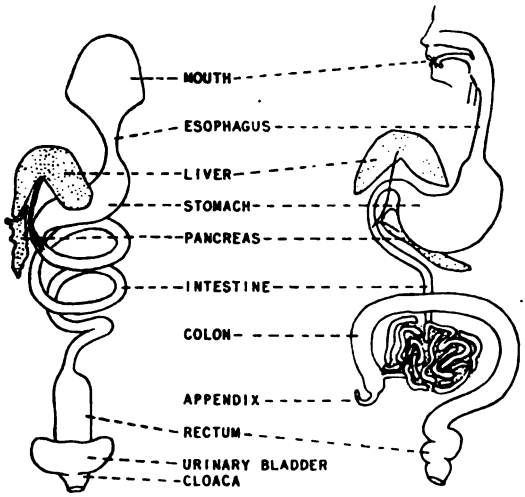


FIG. 91.—The above diagrams are intended to show the difference between the food tubes of the frog and man. Note the shape of the stomach, and the comparative length of the intestine.

In the vertebrate animals the digestive apparatus is known as the *alimentary canal* (Lat. *alimentum* = food). It is composed of the mouth, esophagus, stomach, and intestine. The liver and pancreas are organs which are derived from the intestine in development and aid in digestion. Compare the alimentary canal of the frog with that of man (Fig. 91).

The mouth varies greatly in different animals. Birds and turtles have no teeth. Many reptiles, fish, and amphibians use their teeth for holding their prey but do not chew their food. Many insects

chew their food but have no true teeth. In the matter of chewing they have advanced beyond any of the vertebrates except the mammals. The jaws and teeth of mammals are so constructed that they can grind their food very fine. This is a great aid to digestion and gives this group a great advantage over all others except the insects. It is interesting to note in this connection that the two dominant types of animal life are the insects and the mammals.

Three pairs of *salivary glands* secrete a juice called *saliva* which is passed into the mouth. It serves to soften the food so that it may be more easily swallowed and begins the digestion of carbohydrates. The digestive substances are called enzymes (ĕn′zīms: Gr. *enzymos* = fermented). Their nature is not very well understood, but they are capable of causing chemical changes to take place in other substances without being changed themselves. Because of this a small amount of an enzyme may do a large amount of work if given time. The enzyme in saliva is called *ptyalin*. It does not act in a strongly acid solution. It changes the starch molecule, by a complex process, to several kinds of carbohydrates and finally to *maltose* ($C_{12}H_{22}O_{11}$), a sugar similar to cane sugar. Maltose is ultimately changed to glucose, in the intestine where it is absorbed.

In the stomach the food is churned by the muscular action of the stomach walls and is mixed with *gastric juice* (Gr. *gaster* = a stomach). This juice is secreted by glands in the walls of the stomach and is composed mainly of *hydrochloric acid* (HCl) and two enzymes, *rennin* and *pepsin*. The hydrochloric acid neutralizes the slight alkalinity (alkalies are the opposites of acids) of the saliva and renders the contents of the stomach distinctly acid. Pepsin will not act unless it is in an acid solution; hence, the hydrochloric acid is said to *activate* the pepsin. Pepsin begins the digestion of proteins. They are first reduced to simple proteins and finally to amino acids if digestion continues long enough, but they pass into the intestine before they are reduced this far, and are probably not all reduced to amino acids even there, but some may be absorbed in the more complex form. Hydrochloric acid is also able to digest protein of itself.

Rennin changes casein, one of the proteins of milk, into an insoluble curd. It may be used to curdle milk. This curd is then acted

upon by the pepsin. Another enzyme similar to rennin is found in the pancreatic juice.

Intestinal Digestion.—The food remains in the stomach one or two hours and then passes, a small amount at a time, through the *pyloric valve* (Gr. *pylorus* = gate) into the intestine. Here it is mixed with the *pancreatic juice* from the pancreas, the *bile* from the liver, and the *intestinal juice* from the walls of the intestine.

The bile contains no enzymes. It is alkaline and neutralizes the hydrochloric acid which was secreted in the stomach. The pancreatic juice does not act in an acid medium, and the bile is said to *activate* the pancreatic juice somewhat as the hydrochloric acid does the pepsin. The bile also helps in the digestion of the fats as we shall see.

The pancreatic juice contains three principal enzymes,—*trypsin*, *amylopsin*, and *lipase* or *steapsin*. Trypsin completes the digestion of the proteins, and amylopsin completes the digestion of the carbohydrates. We have discussed the chemical composition of the proteins and carbohydrates in the previous study, and it need not be repeated here. It is enough to say that by adding water to the molecule these two classes of foods are reduced to simpler substances and rendered soluable so that they can pass through the walls of the intestine by osmosis.

We have deferred the discussion of the chemical composition of fats to this place because it can best be studied in connection with digestion.

Fats are composed of an organic acid and an alcohol called *glycerol* ($C_3H_5(OH)_3$) united together to form organic salts called *esters*. Glycerole is commercially known as *glycerine* and is a common toilet article.

$$\underset{\text{Stearic acid}}{3C_{17}H_{35}\cdot CO_2H} + \underset{\text{+ glycerole}}{C_3H_5(OH)_3} \rightarrow \underset{\text{→stearin}}{(C_{17}H_{35}\cdot CO_2)_3C_3H_5} + \underset{\text{+ water}}{3H_2O}$$

Stearin is the chief ester in tallow. Other esters commonly found in fats and oils are *olein* ($(C_{17}H_{33}CO_2)_3\cdot C_3H_5$) and *palmitin* ($(C_{15}H_{31}\cdot CO_2)_3C_3H_5$). There are many others mixed together in various oils.

As is well known fats are insoluble in water. They must be rendered soluble before they will pass through the wall of the intes

tine by osmosis. Soaps are soluble in water and are made by treating a fat with an alkali thus,—

$$\underset{\text{Palmitin}}{(C_{15}H_{31}\cdot CO_2)_3C_3H_5} + \underset{\text{+ alkali of soda}}{3NaOH} \rightarrow \underset{\text{→soap}}{3C_{15}H_{31}\cdot CO_2Na} + \underset{\text{+ glycerole}}{C_3H_5(OH)_3}$$

The lipase of the pancreatic juice causes the alkalies in the intestine to unite with the fats forming soaps and glycerole both of which are soluble in water. If the bile is not present in the intestine, from forty to sixty per cent of the fat eaten is not absorbed and passes out with the feces. Therefore, it is thought that the bile aids in keeping the soaps in solution until they are absorbed.

The intestinal juice has no important enzymes. It is strongly alkaline and serves to keep the contents of the intestine alkaline. The formation of soaps from fat and the action of bacteria serve to render the contents of the intestine acid in character. If this should take place the soaps would not remain in solution, and some would go back to fats or would not be saponified (made into soap) at all. The most important work of the intestinal juice seems to be to maintain the alkalinity of the intestinal contents.

TABLE OF THE DIGESTIVE JUICES

MOUTH: **Saliva**

1. ptyalin—	digests carbohydrates.
2. mucin—	lubricates the esophagus.

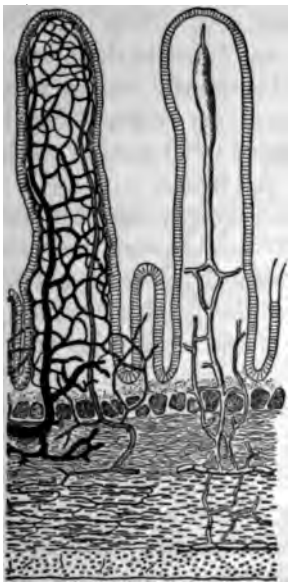
STOMACH: **Gastric juice**

1. hydrochloric acid—	digests protein and activates pepsin.
2. pepsin—	digests protein.
3. rennin—	curdles milk.

INTESTINE: **Bile, pancreatic, and intestinal juices**

1. bile—	activates pancreatic juice.
2. trypsin—	digests protein.
3. amylopsin—	digests carbohydrates.
4. lipase—	digests fats.
5. intestinal juice—	maintains alkalinity in intestine.

Absorption is confined almost exclusively to the intestine and takes place by osmosis of the disolved end-products of digestion through the walls of finger-like processes which project into the interior of the intestine. They are called *villi* (Sing. *villus*) which in Latin means "shaggy hair." Each villus is lined with a network of fine blood vessels and has in its center a duct called a *lacteal*.



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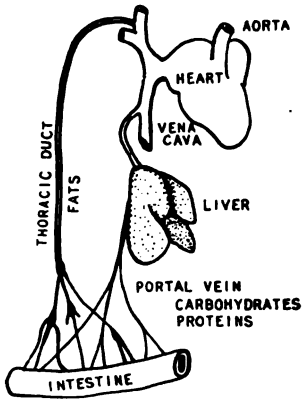

FIG. 93.

FIG. 92.—Diagram of two intestinal villi. In the one to the left the blood vessels are shown, and in the one to the right the lacteal and its connections are seen in the center of the villus. In passing through the walls of the villus the carbohydrate and protein food is first taken out by the blood; and the fat, after passing the network of blood vessels is absorbed by the lacteal. (*Hough and Sedgwick, The Human Mechanism.*)

FIG. 93.—Diagram to show how the digested food gets from the intestine to the circulatory system. Note that the fats enter the blood stream directly, and that the carbohydrate and protein foods must pass through the capillaries of the liver before they reach the heart.

The digested carbohydrates and proteins are absorbed by the villi where they enter the blood and are carried to the liver through the *portal vein*. The carbohydrates pass into the blood in the form of

glucose and are changed into glycogen in the liver and stored temporarily. Only a certain amount of glucose is allowed in the blood under normal conditions except in the portal vein where it may exist in considerable quantity after a carbohydrate meal. Glycogen is changed back into glucose as it is needed, and, thus, a constant quantity is maintained in the blood. This quantity is regulated by the activity of the liver. Glucose may serve as a food when injected directly into the blood in small quantities.

Amino acids and simple proteins are not found in the blood. It is thought that the proteins are reformed in the villi, but not much is known about this as yet. The protein foods are oxidized in the liver and reorganized to be carried by the blood to all parts of the body where they are used mainly for growth and repair.

The fats do not enter the blood stream directly but pass beyond the network of blood vessels in the villus and enter the lacteals. These lacteals unite to form larger tubes and finally form a trunk called the *thoracic duct* which is a part of the lymphatic system and enters the blood system through one of the large veins near the heart. Fats may be absorbed as soaps, glycerole, and fatty acids; but neither of these substances appears in the lymph or blood in appreciable quantity. Therefore, fats, like proteins, are probably reformed in the villi. Small globules of fat are normally present in the blood and lymph.

Laboratory Demonstrations.—Place some starch in saliva. Leave for about twenty minutes, and test for the presence of glucose.

Test the action of acid, neutral, and alkaline pepsin solutions of various dilutions on boiled egg-white. Leave stand over night in a warm place.

Boy's Project.—Can some of the boys prepare the alimentary canal of a frog, rat, or some other animal and mount it in a jar of formaldehyde for an exhibit? Label it and put it in the museum.

Girl's Project.—Can the girls of the class arrange an exhibit of 100 calorie portions of food in combinations to make meals of balanced rations? Government bulletins can be had which are helpful in this work.

17. RESPIRATION AND CIRCULATION

What is the source of the energies of life?

We have seen how foods are oxidized in the bodies of plants and animals and how the energy thus released is utilized for maintaining

the activities of the organism. *It is the fundamental purpose of respiration to furnish the oxygen supply for this process and to help eliminate from the body the products of combustion. It is the fundamental purpose of circulation to carry food and oxygen to places where they are needed and to carry the waste products to the excretory organs.*

Protozoans, sponges, and **jellyfish** have no special organs of circulation or respiration. The protozoans are composed of but a single cell, and oxygen and food are obtained directly from the

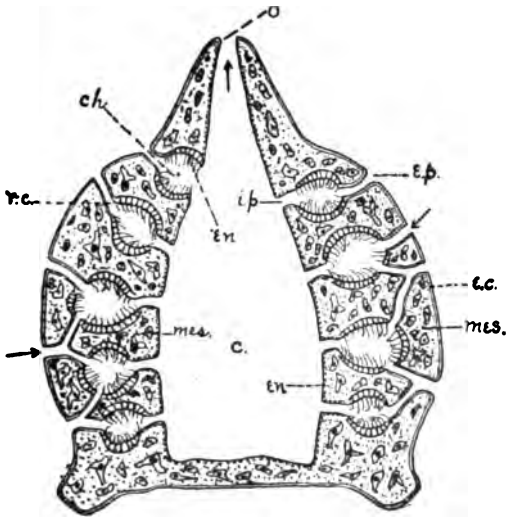

FIG. 94.—Diagram of the circulation of water in a simple sponge. Water enters through the external pores (*ep*), passes through the chambers with flagellated cells (*ch*), through the internal pores (*ip*), into the cloaca (*c*), and out through the osculum (*o*). (*From Galloway.*)

medium in which they live. The sponges have small pores all over the body through which water passes. It flows through the entire body and supplies it with oxygen and food. The jellyfishes are composed of but two layers of cells,—*ectoderm* and *endoderm* (outside and inside skin). The ectoderm is everywhere exposed to the water from which oxygen is absorbed. Food is carried to all parts of the body through canals which branch out in all directions from the stomach. Both food and oxygen pass from one cell layer to the other by osmosis.

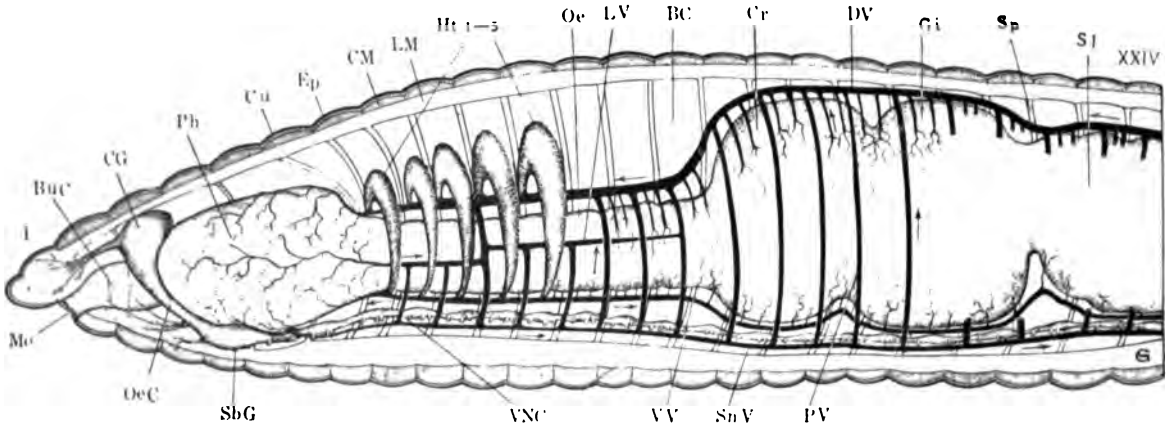

FIG. 95.—Diagram of the anterior end of an earthworm to show the digestive, nervous, and blood systems. The arrows indicate the direction of the flow of the blood. (*From General Zoology Laboratory Directions, by Sigerfoos.*)

BC, body cavity	*Gi*, gizzard	*Ph*, pharynx
BuC, mouth cavity	*Ht*, five pairs of hearts	*Si*, intestine
CG, brain	*LV*, lateral vessel	*Sp*, septa
CM, circular muscles	*LM*, longitudinal muscles	*SnV*, subneural vessel
Cr, crop	*Mo*, mouth	*SbG*, sub-ganglion
Cu, cuticle	*Oe*, esophagus	*VNC*, nerve cord
DV, dorsal blood-vessel	*OeC*, commissure	*VV*, ventral vessel
Ep, epidermis	*PV*, parietal vessels	*I–XXIV*, segments

The earthworm has a good circulatory system but no special respiratory organs. Oxygen is absorbed by the moist skin and is carried by the red blood to all parts of the body. The blood also carries food from the intestine to all parts of the body.

In insects the respiratory and circulatory systems are separate. Oxygen is carried to all parts of the body by a system of tubes called *tracheæ* (Sing. *trachea*). The blood system is poorly developed.

Spiders, scorpions, and the **horseshoe crab** breathe with *lung-books* which are structures containing parallel plates arranged

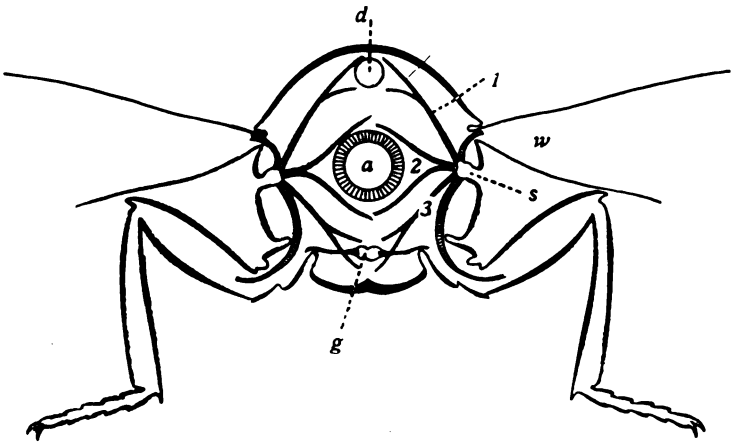

FIG. 96.—Diagram of the cross section of an insect's body to show the distribution of the tracheal tubes (1, 2, 3, etc.). *d*, dorsal blood-vessel; *g*, nerve ganglion; *w*, wing; *s*, spiracle through which the air enters and leaves the tracheal system. Why is it not necessary for the blood to carry oxygen? See also Fig. 33. (*From Folsom.*)

like the leaves of a book. *Crayfish* and *crabs* breathe with structures called gills, but they are much different from the gills of fish. The blood system of these forms is poorly developed but carries both food and oxygen.

Molluscs.—In this group the more primitive, aquatic forms have gills, and the land forms have a lung; but some land forms have apparently gone back to the water to live and retain their lung which is a mere sac in the animal's side. In the higher molluscs the heart is three chambered. They are the only invertebrates which possess

a three chambered heart and where the blood passes through the heart twice in making a complete circuit of the body.

Fish have a two chambered heart and breathe with gills. Their circulation differs from that of other vertebrates in that it passes through the heart but once in making a complete circuit of the body.

Frogs and **toads** have a three chambered heart and breathe with lungs and through their moist skin. They begin life as tadpoles and have a two chambered heart and gills like that of a fish. In the

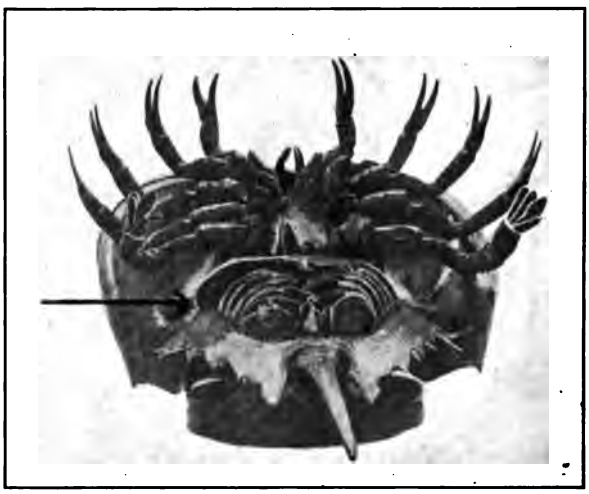

FIG. 97.—Photograph of a horseshoe crab, on its back, to show the lung-book with which it obtains oxygen from the water. It is the structure beneath the abdomen, in the center of the picture. A specimen should be purchased for the museum to illustrate this structure.

fish the blood passes from the heart to the gills, to the body and back to the heart, and to the gills again, and so on. In the frog the blood passes from the heart to the lungs; then back to the heart, and then to the body; then back to the heart, and then to the lungs, and so on. The ventricle of the heart in both forms is single, and oxygenated and deoxygenated blood mingle there to a certain extent in the frog, but the fish heart receives only deoxygenated blood.

Birds and **mammals** have the ventricle divided completely by a partition. This makes a four chambered heart. The flow of the blood is similar to that of the frog, but there is no mingling of pure

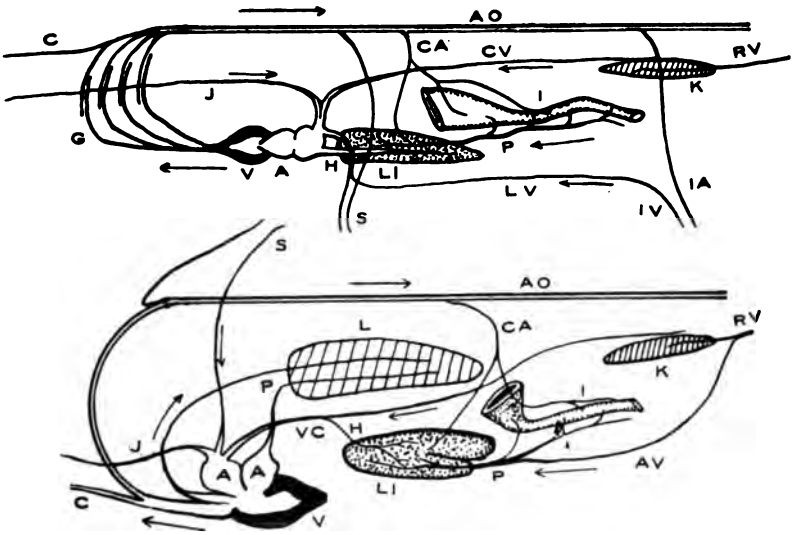

FIG. 98.—The circulation of the blood in the fish and the frog. The diagram for the fish is shown above and the frog below. In the fish the blood enters the heart from the liver (*LI*) through the hepatic vein (*H*), from the pectoral fins through the subclavian veins (*S*), the body-wall through the lateral veins (*LV*), and the pelvic fins through the iliac veins (*IV*). The blood from the dorsal part of the body enters through the jugular veins (*J*) and the cardinal veins (*CV*) which drain the kidney (*K*). In the frog the cardinal veins have been replaced by the single vena cava (*VC*) and the hepatic vein enters this trunk instead of the heart as in the fish. The lateral veins have been replaced by the single abdominal vein (*AV*) which has shifted to enter the portal vein (*P*). The fish heart has one atrium and one ventricle and the blood passes through it once on its circuit of the body. In the frog there are two atria (*A*) and one ventricle (*V*) and the blood passes through the heart twice. This is made necessary because of the development of lungs (*L*) and the pulmonary arteries and veins (*P*). In each form the blood is sent to the head through four carotid arteries (*C*). In the frog the gill arches (*G*) of the fish have been reduced to the arch of the aorta. In both forms the left and right aortas unite to form the dorsal aorta (*AO*). It gives off subclavian arteries (*S*) to the pectoral fins and the fore legs, a cœliac artery (*CA*) to the organs of the abdominal cavity, and iliac arteries (*IA*) to the pelvic fins or the hind legs.

and impure blood in the ventricle of the heart. Birds and mammals are warm blooded and live more active lives than the lower verte-

brates, hence, they require large amounts of oxygen and have a more rapid circulation.

The blood of the vertebrates is composed of a fluid called the *plasma* in which red and white corpuscles float freely. The red corpuscles are by far the more numerous and give the blood its color. Their chief constituent, other than water, is a complex

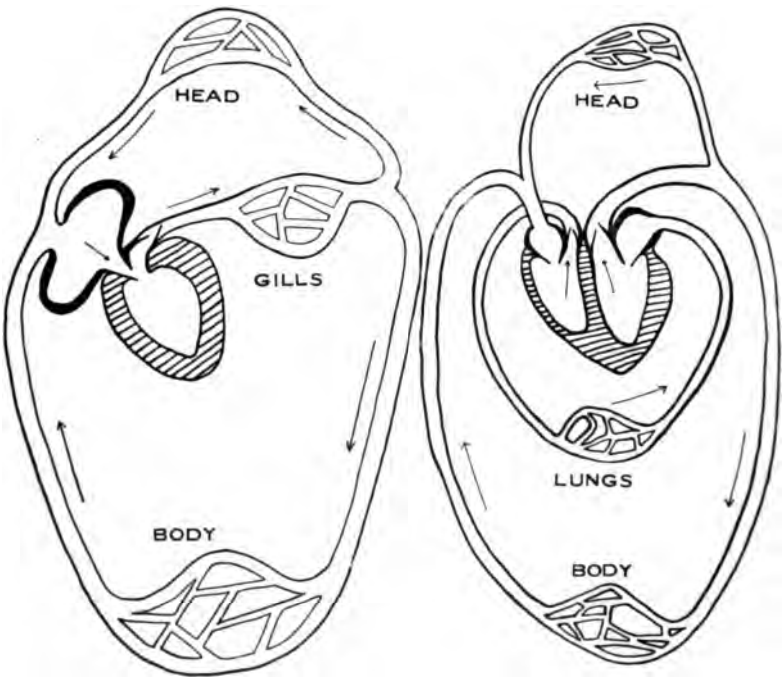

FIG. 99.—Diagrams to illustrate the difference between the circulation in animals with gills and with lungs. Note that in the gilled type the blood passes through the heart but once in making a circuit of the body. In amphibians and most reptiles the ventricle is single. In birds and mammals it is double as in the figure.

protein containing iron, potassium, and phosphorous, called *hæmoglobin*. It is capable of taking up oxygen where it is plentiful and releasing it where it is scarce. When it contains much oxygen it is bright red in color. The blood of the earthworm contains

hæmoglobin, but it is not in corpuscles. It is dissolved in the blood plasma.

The white blood corpuscles are *ameboid* (like an ameba). They change their shape as does an ameba and feed in a similar manner. Bacteria are ingested and destroyed in large quantity when they are present. They assemble in places where infection occurs, and, thus, help the body to fight off disease.

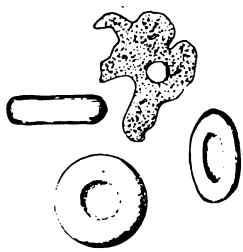

FIG. 100.—Red and white blood corpuscles.

Coagulation.—When the blood flows out of a wound it sets or *coagulates*. This is caused by the formation of fine, white fibers of a complex protein material called *fibrin*. If they are removed as fast as they form, no coagulation takes place. Coagulation prevents bleeding to death when a small artery is opened. If the blood flows from a deep wound in the arm or leg in pulses, an artery has been opened, and a tourniquet should be applied. See illustration. Apply a bandage of this kind to the arm of one of the students in the class. It may be made with a handkerchief and a leadpencil.

Very little is actually known concerning the oxidation of food in the bodies of plants and animals. Proteins are oxidized to a considerable extent in the liver. The oxidation products of proteins are water, carbon dioxide, and some product containing nitrogen. The nitrogenous waste of birds passes off largely in the form of uric acid; that of cattle and horses in the form of hippuric acid, and that of man in the form of urea. These three forms readily break down to form ammonia.

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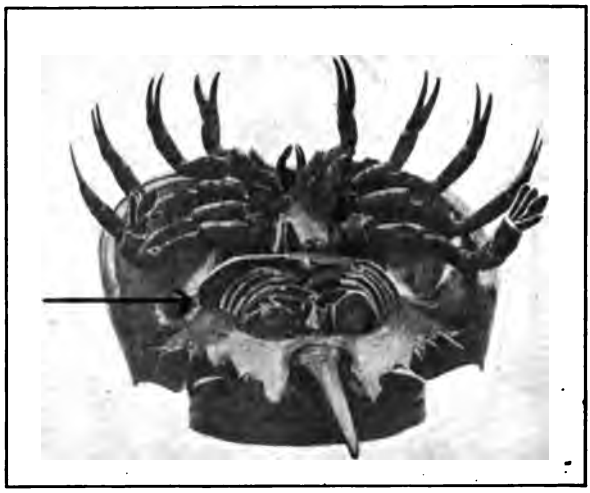

FIG. 97.—Photograph of a horseshoe crab, on its back, to show the lung-book with which it obtains oxygen from the water. It is the structure beneath the abdomen, in the center of the picture. A specimen should be purchased for the museum to illustrate this structure.

fish the blood passes from the heart to the gills, to the body and back to the heart, and to the gills again, and so on. In the frog the blood passes from the heart to the lungs; then back to the heart, and then to the body; then back to the heart, and then to the lungs, and so on. The ventricle of the heart in both forms is single, and oxygenated and deoxygenated blood mingle there to a certain extent in the frog, but the fish heart receives only deoxygenated blood.

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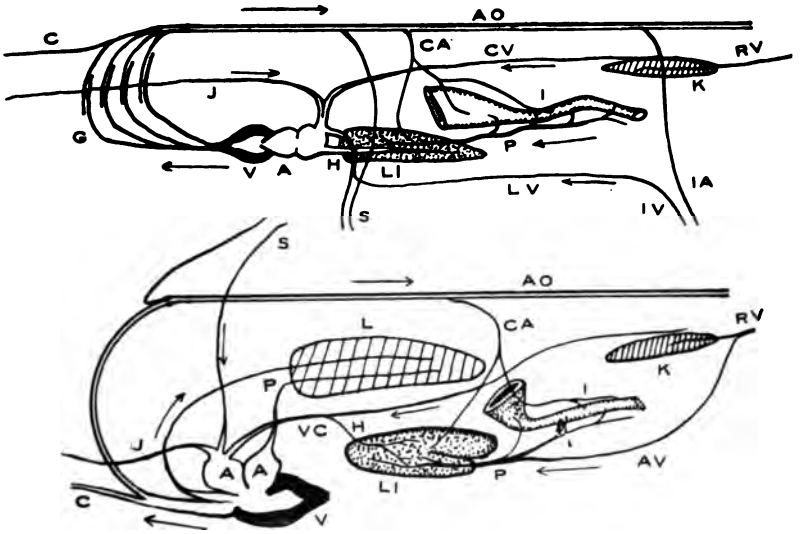


FIG. 98.—The circulation of the blood in the fish and the frog. The diagram for the fish is shown above and the frog below. In the fish the blood enters the heart from the liver (*LI*) through the hepatic vein (*H*), from the pectoral fins through the subclavian veins (*S*), the body-wall through the lateral veins (*LV*), and the pelvic fins through the iliac veins (*IV*). The blood from the dorsal part of the body enters through the jugular veins (*J*) and the cardinal veins (*CV*) which drain the kidney (*K*). In the frog the cardinal veins have been replaced by the single vena cava (*VC*) and the hepatic vein enters this trunk instead of the heart as in the fish. The lateral veins have been replaced by the single abdominal vein (*AV*) which has shifted to enter the portal vein (*P*). The fish heart has one atrium and one ventricle and the blood passes through it once on its circuit of the body. In the frog there are two atria (*A*) and one ventricle (*V*) and the blood passes through the heart twice. This is made necessary because of the development of lungs (*L*) and the pulmonary arteries and veins (*P*). In each form the blood is sent to the head through four carotid arteries (*C*). In the frog the gill arches (*G*) of the fish have been reduced to the arch of the aorta. In both forms the left and right aortas unite to form the dorsal aorta (*AO*). It gives off subclavian arteries (*S*) to the pectoral fins and the fore legs, a cœliac artery (*CA*) to the organs of the abdominal cavity, and iliac arteries (*IA*) to the pelvic fins or the hind legs.

and impure blood in the ventricle of the heart. Birds and mammals are warm blooded and live more active lives than the lower verte-

Oxidation of fats and carbohydrates yields water and carbon dioxide as is shown in the following equation:

$$C_6H_{10}O_5 + 6O_2 \rightarrow 6CO_2 + 5H_2O$$

Glycogen + oxygen → carbon dioxide + water

The energy released by oxidation is used in muscular, glandular, and nervous activities, and in other ways. The more extensive these

FIG. 101.—Photograph to illustrate the method of making a tourniquet.

activities are the larger is the amount of oxygen required. Birds consume large quantities of food and oxygen, and their body temperature is higher than that of mammals. Turtles and frogs can live a year without food and remain under water all the time, if kept cold.

Circulation and oxidation in plants is not so extensive as in animals. Circulation takes place through fibrovascular tissue, as has been explained, and is concerned chiefly with the distribution of food, but some oxygen is carried in solution. In many water plants special tubes occur for carrying oxygen to the roots which being submerged have not good access to air. These air passages serve also to float the stems and leaves.

Outdoor Project.—Appoint a committee of boys to go outdoors and take the pulse of some members. Run a 100 yard race and take it again. Note also the increased vigor of the respiration. The chairman should report to the class. Discuss the causes of this.

Experiment.—Seal a plant in a glass jar and put it in good light. Does it die?

UNIT III. THE RESPONSES OF PLANTS AND ANIMALS

18. SIMPLE RESPONSES OF PLANTS AND ANIMALS

In what ways do plants and the lower animals respond to changes in their environments?

A response is an action resulting from a *stimulus*. If an image is cast on a photographic plate, a chemical action takes place, due to the action of light on silver salts. The light is the stimulus and the reaction is the response. The responses of living things are more complex than those of inanimate things, but it is difficult to draw the line of separation. Certain biologists, called *mechanists*, believe that when we have gained sufficient knowledge, all of the responses of living things can be explained in physical terms. Others, called *vitalists*, believe there is a vital force or principle in living matter that can not be analyzed physically. This conflict can not be settled at present because the proofs are not complete.

Tropisms.—The simple responses of plants and animals are called *tropisms* (Lat. *tropus* = turn). The principal kinds of tropsims are as follows:

Geotropism = reaction to gravity.
Hydrotropism = reaction to water.
Phototropism = reaction to light.
Chemotropism = reaction to chemicals.
Thigmotropism = reaction to touch or contact.
Thermotropism = reaction to heat.
Electrotropism = reaction to electricity.
Rheotropism = reaction to a current in water.

Assigned Projects. Geotropism may be illustrated in various ways by plants, especially seedlings. Hydrotropism may be shown by plant roots as noted below. Phototropism may be shown by plant leaves and seedlings. Chemotropism and thigmotropism may be shown by irritating an earthworm. It will be difficult to illustrate the last three in the table in an elementary course.

Try to keep one or two sensitive plants growing in the laboratory to show thigmotropism in plants.

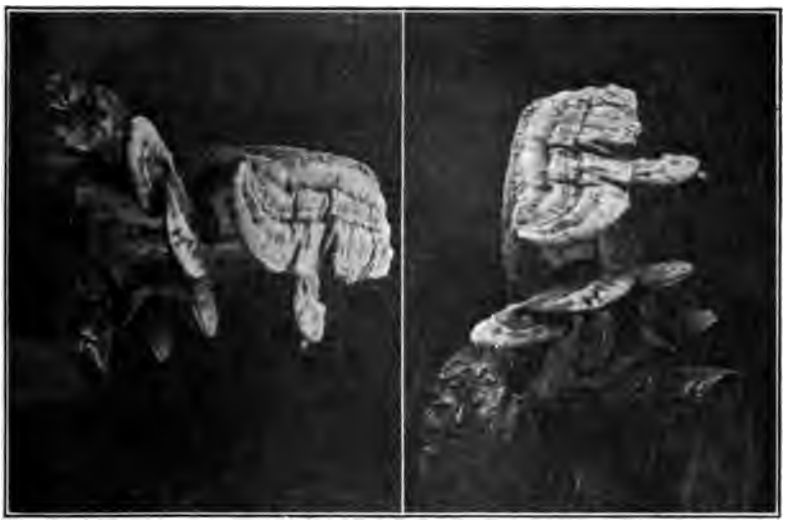


FIG. 102.—Two views of a bracket fungus showing geotropism. The main part of the bracket grew while the tree trunk was standing. After it fell the secondary parts grew out at right angles to the main shelf.

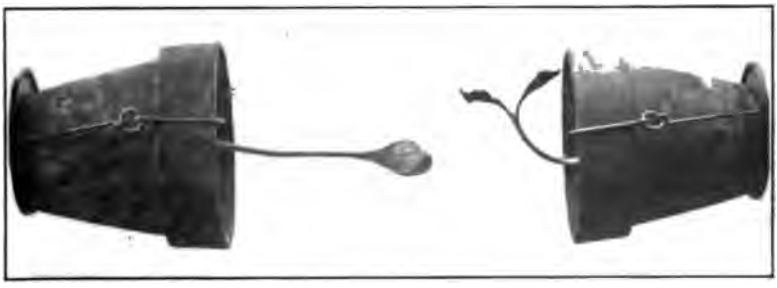


FIG. 103.—Two photographs of a squash seedling to show geotropism. When the flower pot was rotated the plant grew straight out, but when it was stopped the plant bent upward.

"sleep" at night,—*i.e.*, they fold their leaves at the approach of darkness. Wood sorrel, beans, clovers, and the locust tree are among the best known examples. The advantages of this response are not fully known. It has been shown that folded leaves are in less danger of frost than open ones, but this advantage can not apply to tropical plants which fold their leaves.

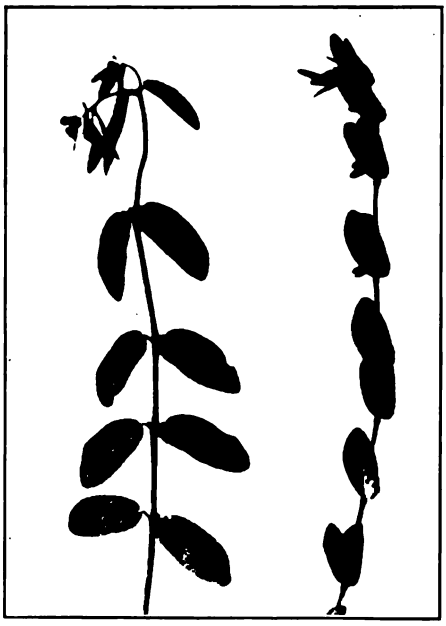


FIG. 106.—Two photographs to show phototropism in one of the milkweeds which "sleeps" at night.

Gourds, jimson weeds, and four-o'clocks open their flowers in the evening. Morning-glories and squashes open their flowers in the morning. Others like the water lily close their petals when the sunlight is bright at midday and open them again toward evening. Night blooming flowers are usually white and are visited by night flying insects such as the hawk moths. Can you mention some other examples of phototropism?

Leaves are sensitive to drought. Those of corn roll up in order to expose less surface to the air. Fruit trees may shed their leaves. The leaves of the olive stand in a vertical position so as to avoid presenting a broad surface to the heat of the sun. The compass plant grows with its leaves vertical and the surfaces facing east and

FIG. 107.—The jimson weed which blossoms at night. (*U. S. Dept. of Agriculture.*)

west. In this case only the edges of the leaves are exposed to the hot, midday sun. In the olive and the compass plant the leaf position is not changed but remains permanent throughout the summer (Fig. 108).

Many plant movements can be explained by *cell turgor*. When a cell is filled with sap it is rigid and enlarged. If the cells on one

FIG. 108.—Phototropism for drought resistance in the compass plant. The leaves point north and south. In taking the picture the camera was pointing directly west, and the sun was at the noon position. Note the shadows on the leaves.

side of a twiner are turgid and those on the other are flaccid, the twiner will bend toward the flaccid side. Some plants, like the

bean, have an enlarged petiole base called the *pulvinus*. By changes in the turgidity of its cells the leaf blade is moved.

We have seen how twiners and tendril climbing vines wrap around their supports as a result of contact stimulus (see study on stems). This is an excellent example of *positive thigmotropism* among plants. When the leaves of the sensitive plant are touched, they slowly collapse. This is an example of *negative thigmotropism*.

FIG. 109.—Two views of a sensitive plant—before and after being touched. The petioles are raised and lowered by the action of pulvini as in the bean. Can you secure some leaves which have pulvini and study them?

RESPONSES IN PROTOZOANS.—If a moving ameba is touched with a pointed object it puts forth new pseudopodia (false feet) and moves away from the irritation. If it comes in contact with food it puts forth pseudopodia and engulfs it. Thus, it may respond positively or negatively to contact. It reacts negatively to sugar, sodium chloride, and many other chemicals in solution. At freezing temperature no activity takes place. As the temperature is raised the animal becomes more and more active until about 85° F. is reached when its activity again diminishes until about 90° F. is

reached when activity ceases. Thus, there is a ***minimum***, ***optimum***, and ***maximum*** temperature to which amebas respond. The optimum being the temperature best suited to its activities. If a weak electric current is passed through an ameba it contracts and moves toward the negative pole. It responds negatively to light unless the light is very strong, when it stops moving and contracts. We have pointed out five tropisms of the ameba. Can you name them?

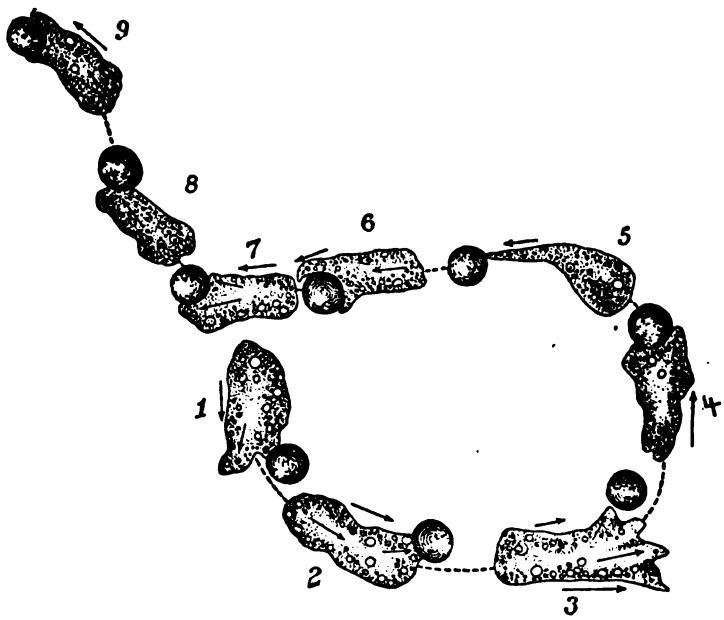


FIG. 110.—Positive tropism in ameba, showing how one followed an encysted euglena in an effort to engulf it. At 3 and 5 the cyst rolled out of contact and was nearly lost. Note the changes in direction taken by the ameba and the persistency of the ameba's pursuit. The cyst was lost at 9 by the interference of another protozoan. (*From Jennings.*)

Euglena is a protozoan containing chlorophyll and is a favorable object for the study of *phototropism*. If the light is too bright it moves away. If too dim it moves toward the light. If a dish is arranged so that one side is very light and the other shaded, it will

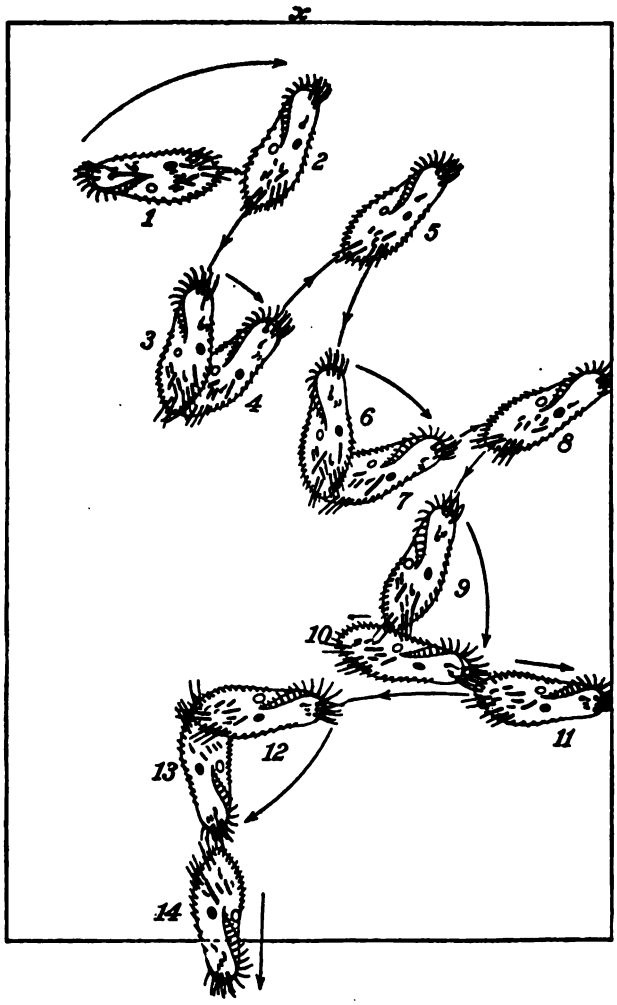


FIG. 111.—Diagram of the avoiding reaction as shown by *Oxytricha*, a relative of *Paramecium*. It is in a rectangular trough which is heated at *x*. It can not turn to the left, hence, at 1 it turns to 2 where it is strongly stimulated by the heat. It then moves back to 3 and turns to 4 from where it moves forward only to encounter the heat again. It backs up to 6 turns to 7 and goes forward to 8 where it experiences thigmotropism with the side of the trough. By continuing to try, after four errors, it finally escapes at 14. (*From Jennings.*)

occupy a position between the two extremes. This is the optimum where photosynthesis takes place the most favorably. See Fig. 83.

Project.—Let some student work out this experiment and report to the class. Euglena may be found in almost any pond. They live and thrive in glass jars in the laboratory.

Paramecium swims by vibrating cilia in the water. If it comes in contact with an object or an unfavorable environment, it stops, reverses the movement of the cilia and swims backward a short distance; then turns and goes forward in a different direction. If it again encounters the unfavorable stimulus, it repeats the process until it finally escapes. This is called the *method of trial and error*, and the negative response is called the *avoiding reaction*.

CONCLUSION.—In the single celled animals reactions are expressed in their simplest terms. There is no evidence of reason or of memory, but pleasure and pain are illustrated in a simple way by the avoiding reaction. "All together, there is no evidence of differences of fundamental character between the behavior of the Protozoa and that of the lower Metazoa (many celled animals). The study of behavior lends no support to the view that the life activities are of an essentially different character in the Protozoa and the Metazoa. The behavior of the Protozoa appears to be no more and no less machine-like than that of the Metazoa; similar principles govern both." (Jennings, *Behavior of the Lower Organisms*).

Laboratory Study.—Raise some paramecia in a jar of water in which some chopped hay has been placed, and if there are good microscopes available, the avoiding reaction may be observed.

19. THE CHEMICAL AND TACTILE SENSES

How do animals become aware of the chemical conditions of their environments?

The earthworm lives in burrows in the ground and has no special sense organs; but if it is touched, it quickly contracts and moves away from the stimulus. Nerve endings which are sensitive to contact are situated in the surface of the body, and from these, nerve fibers pass in to the central nervous system. These fibers

carry impulses from the surface of the body to ganglia in the central nervous system where the impulse is transferred through fibers to other nerve cells—motor nerve cells—which pass it on to muscles in the body wall. This outgoing impulse causes the muscular contraction which draws the worm away from the irritation. A simple response of this kind is called a *reflex*, because the impulse is "reflected" from the ganglion to produce the response.

Tentacles.—Certain relatives of the earthworm have developed processes around the head which are used as tactile organs and in some cases for grasping. They are also common among the cœlen-

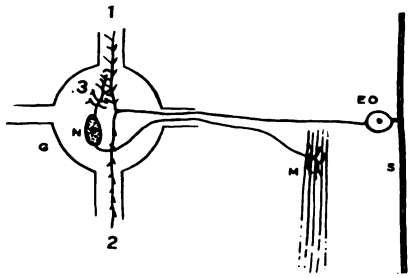


FIG. 112.—Diagram of a reflex action in the earthworm. An irritation of the skin *S* is taken up by the end-organ *EO* and is carried to the ganglion of a somite *G* and is distributed to three regions—toward the head 1, and toward the tail 2, and to another nerve fiber of the motor system in the same ganglion 3. This nerve fiber has its nucleus in the ganglion at *N*, and sends out an impulse to a muscle at *M*. The muscle contracts, completing the action and producing a response to the original stimulus without necessarily involving the other ganglia toward the head or tail.

terates and molluscs, being present in hydra, sea-anemones, squids, the octopus, snails, and cuttlefish (Figs. 19 and 114).

Cuticular hairs are possessed by many of the arthropods; especially spiders, crabs, and insects. They are organs of touch, and are formed from the outer layer of the animal's body which is called the *cuticle*. The hairs themselves are not sensory; but when they are touched, they are moved. This movement sets up an impulse in nerve endings at their bases.

Antennæ are the special sense organs of insects and crustaceans. They are also possessed by some segmented worms, centipeds, and millipeds; and are primarily tactile organs, but are also used for

hearing and smelling in some forms. The lobster has a long, slender pair and four smaller ones called *antennules*. They are all mov-

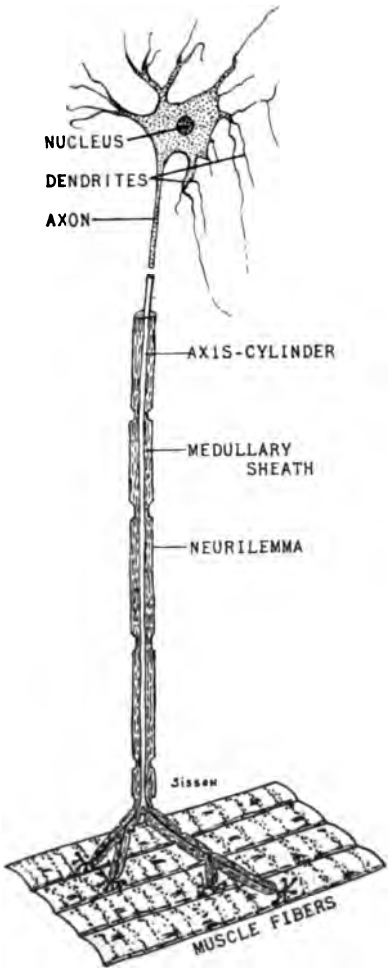


FIG. 113.—Diagram of a typical nerve cell (neuron) to show its parts.

able and can be put forth in different directions to investigate the surroundings. (See Fig. 115).

The antennæ of insects are often very complex in structure. Some are long, jointed threads; some are club-shaped; some plume-like; and some have flat discs at their ends. It is interesting to watch two ants which meet in their runways. They often stop and feel one another in curious ways with their antennæ and then proceed with the air of having received some important information. Bees appear to be able to recognize the difference between the members of their own hive and strangers by means of their antennæ.

FIG. 114.—Photograph of a tube worm taken from its burrow. They live in the mud at the bottom of the sea and extend their tentacles from the burrow.

The whip scorpions feel with their first pair of legs which are very long and slender. In the harvestman the second pair of legs is longer than the others. When they are disturbed, they raise these legs and move them around in the air.

Cats and many other animals have stiff hairs around their mouth and eyes. The bases of these hairs are well supplied with nerve

FIG. 115.—Photograph of the head and antennæ of a lobster. Note that it has two kinds,—a pair of long single ones and a pair of short double ones.

FIG. 116.—Photograph of a whip scorpion. The first pair of legs and the tail-bristle are used for feeling.

endings. These hairs are especially prominent on animals which prowl around at night.

The tongue of the snake is probably used for touch, taste, smell, and hearing. When a snake is excited, its forked tongue darts out and in its mouth continually, and the tip is vibrated in the air. Many people think the snake's tongue is poisonous, but it is an entirely harmless organ.

In man, we commonly recognize the six senses of touch, taste smell, hearing, equilibrium, and sight. Of these the sense of touch is the most fundamental. Man has no special organs of touch as have the insects, but the skin of the face and fingers is very sensitive.

The Chemical Senses.—The senses of taste and smell are spoken of as the *chemical senses* because their operation depends upon chemical action. Very small quantities of certain gases in the air stimulate special cells in smelling organs, called *olfactory organs*. The method by which one odor is distinguished from another is not very well understood. The sensory cells in olfactory organs are very much alike and are simple in structure, so far as can be seen with the aid of the microscope.

The special organs of taste are known as *taste buds*. In mammals they are found chiefly on the tongue. In man the buds at the tip of the tongue give the qualities of sweetness and salt the most readily; those at the base of the tongue, bitter; and those along the edges, salt and sour. What the sensations of taste in other animals are like, we do not know. We simply know that they taste. A substance, in order to be tasted, must be in solution. Insoluble substances have no taste. Why?

As is to be expected, the taste buds of most animals are located in the mouth or on the mouth parts. In insects the smelling organs are usually located on the antennæ but may be on the mouth parts.

On the surface of the body of the earthworm, in the grooves between the segments, are situated many end organs of chemical sense. It can, therefore, *smell* or *taste* over its entire body-surface. When the worm is contracted, these organs are folded into the grooves between the segments and stimulation is reduced. "There is also one type of sensation which is apparently localized at the anterior end. If an earthworm is allowed to crawl about on a moist surface

of limited area, it withdraws when it comes to dry spots at the edge, but if the prostomium (or upper lip) is removed such reactions cease. The ability to discriminate between wet and dry surfaces

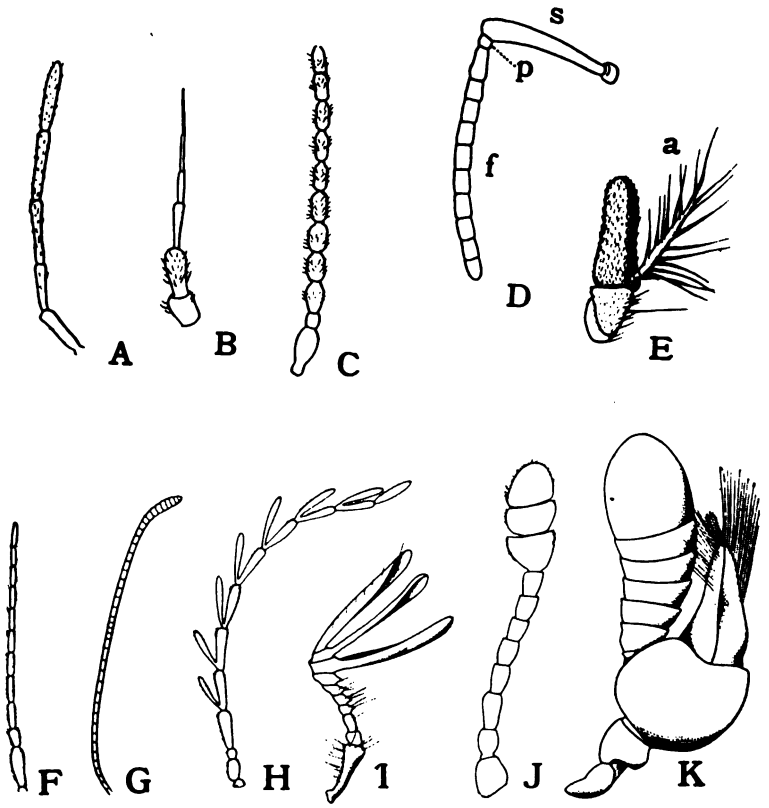


FIG. 117.—Various types of insect antennæ. The feelers of insects are more varied and complex than those of any other class of animals. (*Folsom.*)

is, however, the only sense that is known to be thus localized." A. S. Pearse, *General Zoology*.

In the promethea moth (*Callosamia promethea*) the antennæ of the males are larger than those of the females. Mayer found that the males find the females by the scent given off from the abdomens of

the females. If the antennæ of the males are coated with a substance, like paraffin, they are unable to locate the females. When the coating is removed, they find them in the usual way.*

FIG. 118.—Antennæ of the male and female cecropia moth. *A*, male; *B*, female (*Folsom.*)

Laboratory Suggestions.—A nerve cell may be studied from charts which have been purchased or redrawn by some student, or from lantern slides.

Tentacles, cuticular hairs, and antennæ may be observed and in some cases sketched from life or preserved specimens.

Taste buds may be studied from charts, lantern slides, or models. Perhaps some student can make a model of a taste bud for the museum.

The well known experiment to show the relative importance of taste and smell by holding the nose and eating bits of apple, potato, carrot, etc. may be performed before the class.

20. SOUND AND HEARING

What is sound, and what is its relation to animal life?

To the biologist sound is a sensation. To the physicist it is a vibration which may be detected by the ear. Our ears are limited as to the range of vibrations which they may perceive. It is probable that many vibrations which are unnoticed by us are perceptible to some of the lower animals. Sounds differ in three respects: (1) loudness, (2) pitch, (3) quality or timbre.

* Mayer, A. G. *On the Mating Instinct in Moths, Psyche* Vol. IX, pp. 15–20 1900.

The loudness of a sound depends upon the amplitude (magnitude) of the vibrations and upon the area of the vibrating body. If a drum is struck forcibly the sound is louder than when struck gently, —also, if a larger drum is struck a louder sound will be given off.

Pitch depends upon the number of vibrations given off per second. Middle C on the piano is 258.7 vibrations per second. The average human ear can perceive all vibrations btween thirty and 30,000 per second. The lowest note which the human voice can give is about 64 vibrations per second and the highest is about 1040.

Quality.—If a tuning fork is sounded in air, and then its stem is pressed against a table, the nature of the sound changes. This is partly due to the fact that extra vibrations, called overtones, which differ from those of the fork when sounded alone, are set up in the table. Also, if the same note, with the same loudness, is sounded on a piano, an organ, and a horn the three sounds are distinguishable. This difference in sounds, due to overtones, is called *quality* or *timbre*.

How do animals hear?

If you steal up on an earthworm when it is extended from its burrow and jar the earth in its vicinity, it will withdraw rapidly. The jar is a vibration in the soil and is received in some way by the

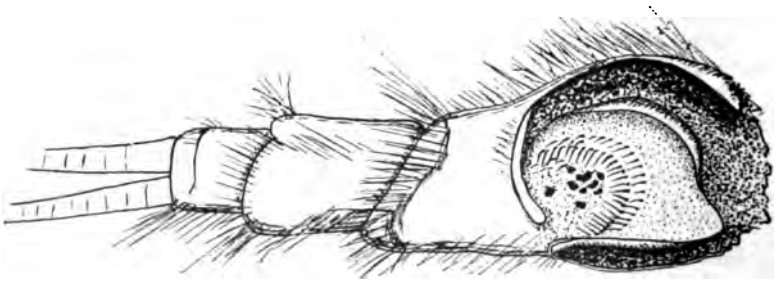


FIG. 119.—The statocyst of the lobster. The side of the segment has been cut away to show the interior. Note the sand grains enclosed by a double row of sensitive hairs.

nervous system of the worm, but no special sense organ for the detection of vibrations can be found.

The "ear" of the lobster is a curious structure called a statocyst (Gr. *statos* = standing + *cystis* = a sac). It is a pit in the upper

surface of the basal segment of each pair of antennules. The pit is lined with a number of sensory hairs, and its interior is in free communication with the water. It contains several small grains of sand which are put there by the lobster itself after each shedding of its shell; for when the creature molts the lining of the statocyst is shed, and the sand grains are lost. This structure was formerly thought to be a hearing organ but is now known to be a balancing organ.

The statocyst operates by the sand grains striking against the sensory hairs on its inner surface. Kreidl gave shrimps which had

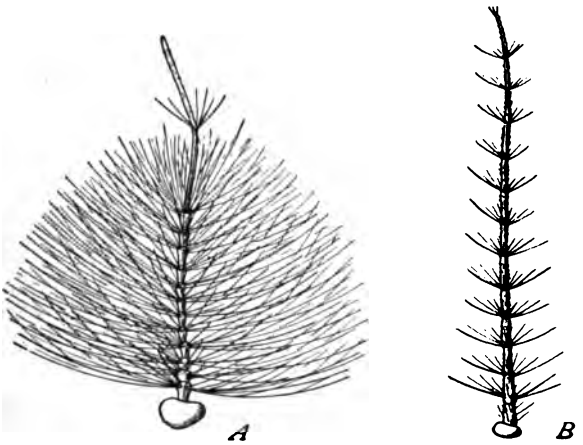


FIG. 120.—Antennæ of the common mosquito. *A*, male; *B*, female. (*Folsom.*)

recently molted, iron filings in place of sand to put in their statocysts. When a strong electro-magnet was held near them they took up a position corresponding to the resultant of the pull of gravity and that of the magnet. Statocysts have been found in crustaceans, jellyfish, segmented worms, and molluscs.

The male mosquito finds the female by hearing her buzz. As she flies her wings set up vibrations in the air which cause the delicate fibriles of the plume-like antennæ of the male to be set in motion. This movement can be observed by placing a male under a microscope and allowing a female to buzz near by. Mayer found that

when the female buzzes she sounds a note which is approximately C″ which is 512 vibrations per second. If a tuning fork of this frequency is sounded near a male mosquito it sets up vibrations in his antennæ. "The male probably turns his head until the two antennæ are equally affected by the note of the female, when, by going straight ahead, he is able to locate her with great precision" (*Folsom*).

The ears of the grasshopper are situated on each side of the first abdominal segment. Each consists of a membrane stretched over

FIG. 121.—Photograph of the ear of a grasshopper. It is the light area just below the second pair of wings. Enlarged.

the cavity of the first abdominal spiracle. It is supplied with nerves which carry impulses to the ganglia in the thorax. Such an organ is called a *tympanum* (Gr. *tympanum* = a drum). Tympanal organs are found in various places on other insects. Although statocysts are quite generally distributed among invertebrates, insects are not known to possess them, and are the only invertebrates known to have true hearing organs.

The Vertebrate Ear.—In the vertebrates the organ of hearing and that of equilibrium are situated together in the ear. The ear consists essentially of a cavity called the *labyrinth* which is lined in

places with sensory cells. In the lamprey eels the labyrinth is a simple, oval sac. In fish it is partly divided into two chambers,—the *sacculus* and *utriculus*. Connected with the utriculus are three semicircular canals arranged at right angles to each other so that two are vertical and one is horizontal. All of the higher vertebrates possess the utriculus and its three canals arranged essentially as they are in the fish. This part of the ear has nothing to do with hearing but is an organ of orientation and equilibration. If this organ is rendered functionless the fish can not swim in an upright position.

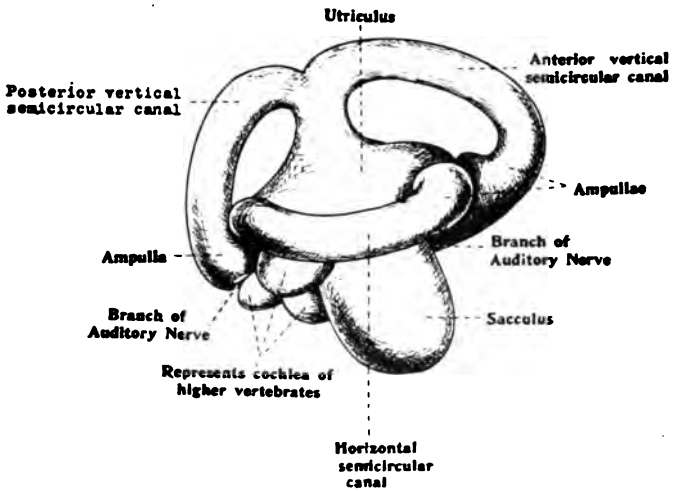


FIG. 122.—The labyrinth of the right ear of the frog, seen from the outer side. Note the three processes which represent the cochlea of the higher forms. (*From Guyer, redrawn from Borrodaile.*)

In all vertebrates, except fishes, a projection is found on the forward side of the sacculus. In frogs and reptiles it is a mere pocket. In birds it is a long tube, and in mammals it is very long and coiled like a snail shell. Because of its shape it is called the *cochlea* (Lat. snail shell).

Two partitions extend throughout the entire length of the cochlea and divide it into three parallel, coiled chambers which are filled with fluid. The middle chamber contains the sensory cells which receive the sound vibrations. They are situated on one of the longi-

tudinal partitions of the cochlea called the *basilar membrane*, and together with other cells, make up the *organ of Corti*. Projecting into the fluid of the middle chamber, from each sensory cell, are about twenty rod-like processes which are believed to be the end-organs of hearing.

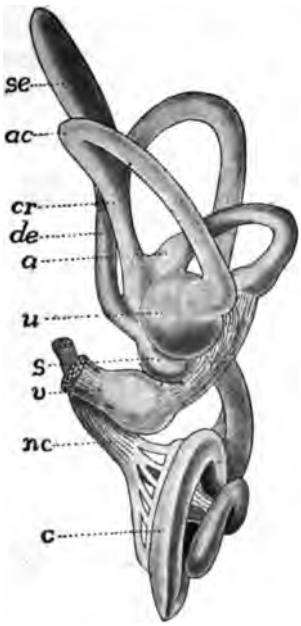


FIG. 123.

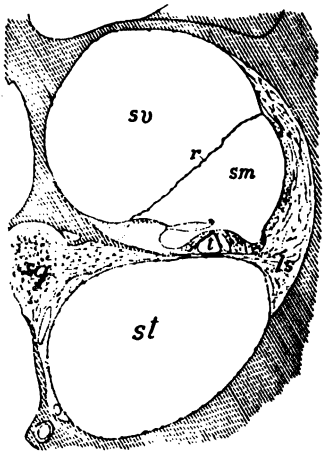


FIG. 124.

FIG. 123.—Labyrinth of a human embryo. *a*, ampulla; *ac*, anterior canal; *c*, cochlea; *cr*, crus of the anterior and posterior canals; *de*, endolymph duct; *nc*, cochlear nerve; *s*, sacculus; *se*, endolymph sac; *u*, utriculus; *v*, vestibular nerve. (*From Kingsley.*)

FIG. 124.—Diagram of a cross section of the cochlea to show the three vestibules and the organ of Corti. *sv*, *sm*, *st*, scalæ vestibuli, media, tympani, respectively; *t*, tunnel in the organ of Corti. (*From Kingsley, after Schneider.*)

The structures we have just described constitute the *inner ear*. The middle ear is a cavity connected with the mouth by a tube called the *Eustachian tube* after its discoverer. The middle ear is separated from the exterior by the *tympanic membrane*. Sound waves cause this membrane to vibrate, and the vibrations are transferred across

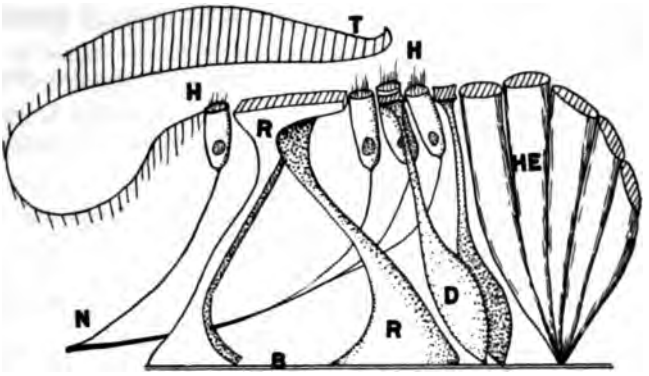


FIG. 125.—Diagram of the organ of Corti. *B*, basilar membrane; *D*, Deiter's cells; *H*, inner and outer hair cells; *HE*, Henson's cells; *N*, nerve tract from hair cells; *R*, inner and outer pillars of Corti; *T*, tectorial membrane.

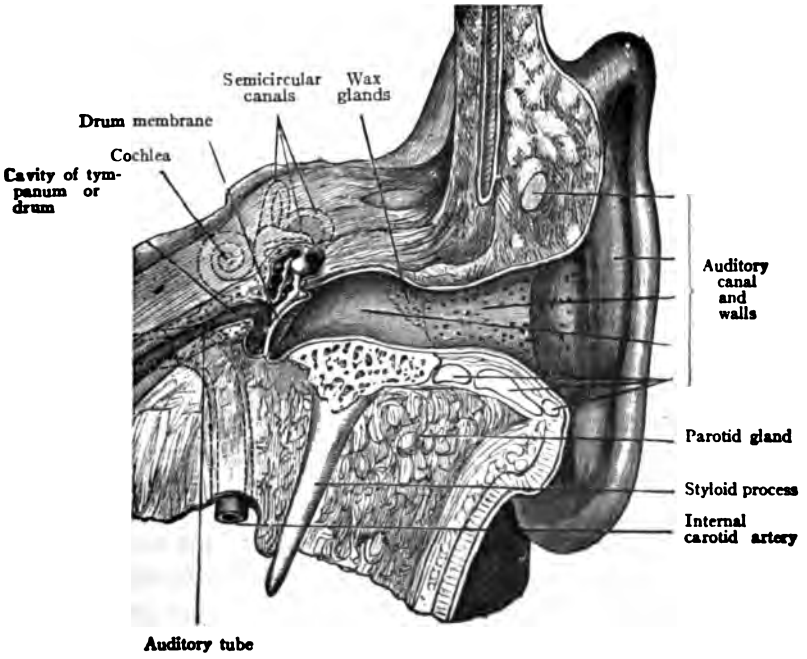


FIG. 126.—Diagram of the human ear. (*From Bundy, after Morris.*)

the middle ear to the labyrinth by three small bones in mammals, which act as a set of levers.

The mammals are the only animals which have an outer shell to reflect the sound waves into the ear. In the frog the tympanic membrane is flush with the side of the head. Snakes, salamanders, and fishes lack both the outer and middle ear.

Teacher's Demonstration.—Set up a pendulum to illustrate vibration. Show the effect of changing the length of the string. Show that the number of vibrations is independent of the length of the arc through which the ball swings. How does the pendulum illustrate the phenomena of pitch? Show the four laws of vibration of strings also.

Students may be asked to reproduce from memory a diagram of the human ear. It may be done on paper at the desks or on the board. Label completely.

21. LIGHT AND VISION

How do animals see?

LIGHT is believed to be a transverse wave motion in the ether which is supposed to pervade all space. These waves are a form of energy

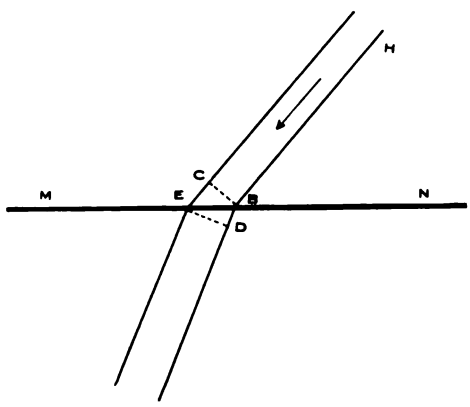


FIG. 127.—Diagram to illustrate refraction.

traveling in straight lines at the rate of 186,000 miles per second. At this rate light would travel around the earth at the equator about seven and one-half times in one second.

Refraction.—The speed of light is not the same in all transparent substances. In comparatively dense media like glass and water,

it travels more slowly than in air, hence if a beam of light passes from air to water, or *vice versa*, it is bent at the line of junction of the air and the water. A reference to Fig. 127 will make this clear. If a beam of light falls on the surface of water *MN* at an angle as *HBN*; when the wave front CB strikes the water, the side B will enter before the side C. Since light travels more slowly in water than in air, the side B will be at D when the side C enters the water at E. This will change the direction of the wave front and at the same time widen it. This behavior of a beam of light is known as ***refraction***.

When a beam of light falls on the convex surface of a lens, it is refracted to a point or *focused*. The action of all lenses depends upon this phenomenon of refraction.

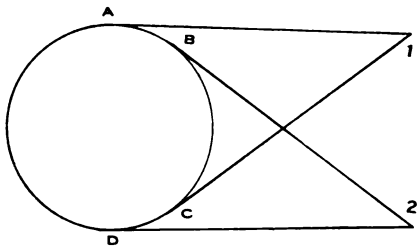


FIG. 128.—Diagram to illustrate binocular vision.

VISION has three aspects: (1) intensity, (2) dimension, (3) color.

1. **The intensity of light** varies inversely with the square of the distance from the source of the light, *i.e.*, if we move up to one-half as far away the intensity will be four times as great, or in other words, the nearer we are to a light the brighter it is. Many of the lower forms of life are sensitive to light and shadow only,—*i.e.*, their vision is limited to distinguishing between different intensities of light.

2. **Dimension** is a geometric quality. Eyes that possess lenses usually distinguish the shape or outline of the object seen. If the animal possesses more than one eye the three dimensions may be seen more easily. This may be made clear by a reference to Fig. 128. ABCD represents a sphere. The eye at 1 sees the half sphere AC, while the eye at 2 sees the half sphere BD, hence the surface is known to be curved, each eye seeing around the side a little farther than the other.

3. **Color** depends upon the wave length of light, very much as pitch depends upon the wave length of sound. In violet light the wave length is about .000042 centimeters; in red about .000068 centimeters. The wave lengths of the other colors lie between these limits. Only the most highly developed animals are able to detect color.

The little green protozoan, **euglena**, has a small red spot near the anterior end of the body. We have seen in a previous study that euglena is very sensitive to light. The red spot is called an "eye,"

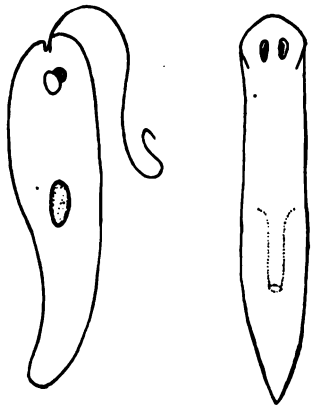


FIG. 129.—Diagrams of euglena and planaria to show the location of their light-sense organs. Can you secure some living specimens and study their eyes under a microscope? Note that there is a clear space in conjunction with each "eye." Planarians seem to be cross-eyed.

and is perhaps the best example of an organ of special sense, other than tactile structures, in the PROTOZOA.

The **earthworm** seldom emerges from its burrow in daylight. Although, it has no eyes, it is sensitive to light over its entire surface, —especially so toward the head end of the body. Hydra is also sensitive to light, and like the earthworm has no special light-sense organs.

Planarians are flat worms which live in mud and decaying matter at the bottom of ponds. Near the anterior end of the body, on the *dorsal* surface, are two pigment spots. They are organs of vision

and are examples of the simplest kind of eyes. Eyes of this type are also found in some jelly-fish.

In the **mollusks** we find a great variety of eyes. In some they are mere pigment spots resembling those of the flat worms, but some have the pigmented areas depressed to form a concave retina. In some the cuticle is thickened to form a lens over the retina, and in the higher forms this lens is folded into the eye and is covered over by a second layer of cuticle which is transparent and forms a cornea. In the octopus, squids, and other cephalopods the eye resembles the vertebrate eye in many details and is a very efficient type.

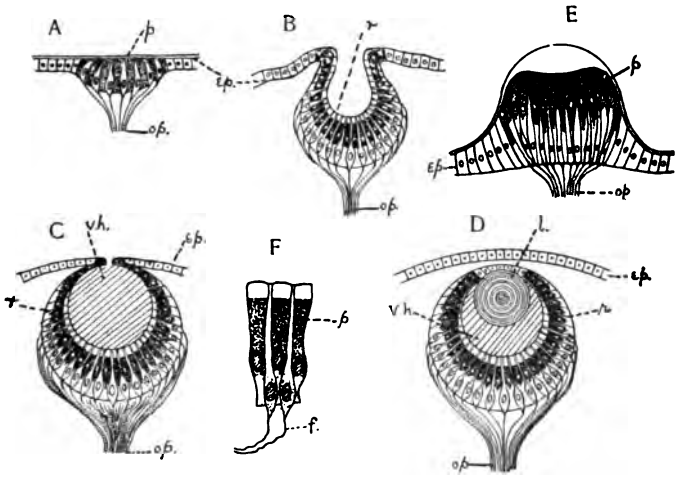


FIG. 130.—Diagrams showing stages in the increasing complexity of eyes of various invertebrates. *A*, a simple pigment spot; *B*, pigment cells in a pit; *E*, pigmented area elevated instead of depressed; *C*, a pin-hole type of eye. The pit has become nearly closed. *D*, a completely closed pit with a lens and cornea; *F*, cells from the retina, highly magnified. *ep*, epidermis; *f*, nerve fiber; *l*, lens; *op*, optic nerve; *p*, pigment cells; *r*, retina; *vh*, vitreous humor. (*From Galloway.*)

In the **arthropods** we find three types of eyes: (1) the ocellus, (2) the compound eye, (3) an intermediate type. These types vary considerably in different forms.

The **ocelli** are typically three in number in the insects and six or eight in the spiders. Each consists of a thickened layer of cuticle which serves as a lens. Beneath this is a transparent region, and beneath this is the retina.

The **compound** eyes are found in insects, crustaceans, and the horseshoe-crab, *Limulus*. The cuticle is divided into many four or six sided facets which have the form of biconvex lenses. Beneath the cuticle is a group of transparent *lens* or *cone cells*. They are followed by a long, central, transparent rod or group of rods (*rhabdomeres*), and are surrounded by a group of elongated cells which constitute the *retinula*. Each division of the eye (*omatidium*) is lined with pigment cells, and some of these are movable so as to serve as an iris for the regulation of the amount of light which enters the omatidium.

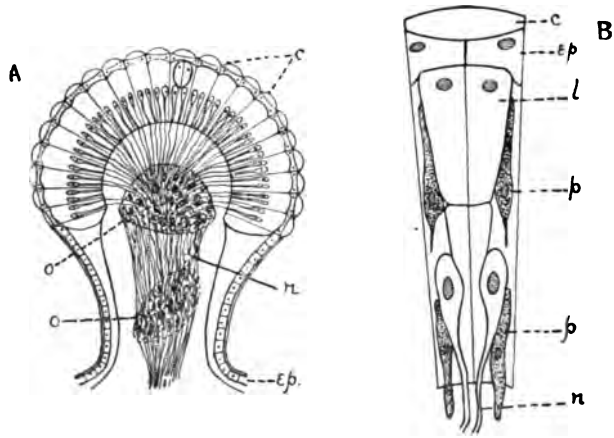


FIG. 131.—Diagram of the compound eye of arthropods. *A*, section through the eye; *B*, section through a single facet. *C*, cuticular facets; *ep*, epidermis; *l*, group of cells forming a lens-like body; *n*, optic nerve fibers; *o*, optic ganglia; *p*, pigment cells. (*From Galloway.*)

It is believed that compound eyes may form two kinds of images: the *mosaic image* when each omatidium functions independently, and an "apposition image" is formed; and the *superposition image* when they function together to form one image. In this case the pigment lining between the omatidia contracts and permits the light to pass from one division to another, the rays superimposing parts upon counter parts to make a stronger impression. The eyes are believed to function in this way in weak light. The compound eye is not well adapted to long range vision. Insects probably do not perceive dimension beyond two yards with their compound

eyes. They are well adapted, however, to perceive movement and direction. Many insects perceive color.

The **intermediate** type of eye is found in the scorpions. They have simple ocelli on the sides of their heads and a pair of median eyes on the upper surface. These median eyes are like the compound eyes in that the retinal elements are arranged in groups, but they resemble the simple eyes in that the cornea is single instead of being divided into facets. It is believed that all three types arose from an ancestral type that was simpler in structure than the ocellus.

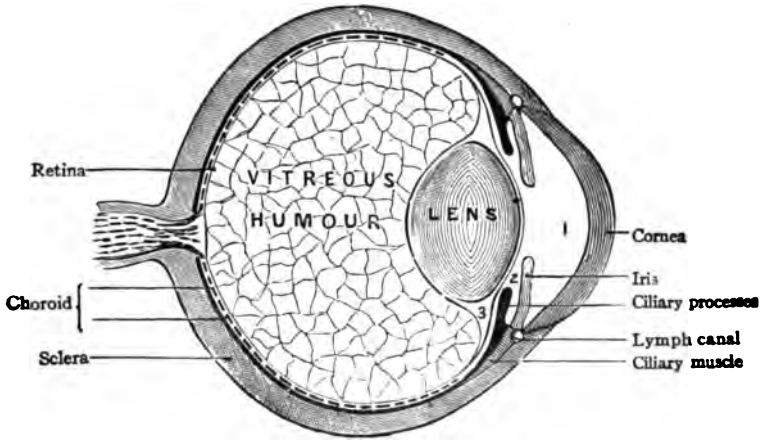


FIG. 132.—Diagram of the human eye. (*From Bundy after Holden.*)

The eyes of the **vertebrate animals** are all of the same type. A diagram of the vertebrate eye is shown in Fig. 132. Its essential features are: the transparent *cornea*, the *aqueous humor*, the muscular *iris* for regulating the amount of light, the biconvex *lens*, the *vitreous humor*, and the *retina*. The image formed by the lens is real and inverted. In the fishes the lens is moved forward and backward, somewhat like a camera lens, in order to obtain a distinct image. In the higher forms the shape of the lens is altered by muscles in focusing.

It is interesting to note that the three most successful phyla of animals—namely, the ARTHROPODA, MOLLUSCA, and VERTEBRATA,

have each developed an organ of vision peculiar to the group. The arthropods have developed the ocellus for long range vision and the compound eye for more accurate, close-range work. The eye of the MOLLUSCA culminates in the cephalopod eye. Its resem-

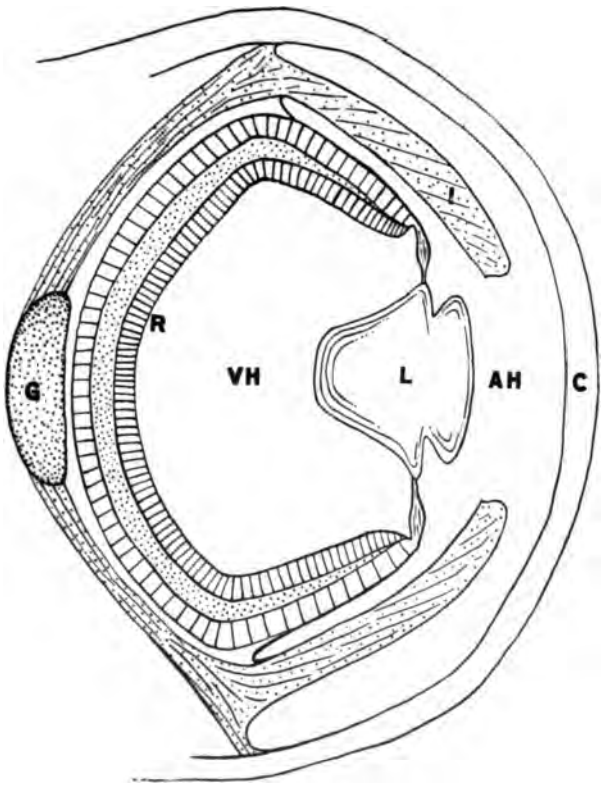


FIG. 133.—Diagram of the eye of a cephalopod mollusc for comparison with the vertebrate eye shown in the previous figure. *AH*, aqueous humor; *C*, cornea; *G*, optic ganglion, not found in the vertebrate eye. Nerve fibers from the retina collect here. They are not shown in the figure. *I*, iris; *L*, lens; *VH*, vitreous humor; *R*, retina. Make a list of the similarities and dissimilarities.

blance to the vertebrate eye is a good example of the *principle of convergence*, which is that similar organs are developed by different groups of animals to perform similar functions. However, if they have had a separate origin they are never exactly alike.

In spite of the great resemblance between the cephalopod and vertebrate eyes, there are some important differences. In vertebrates the retina is developed as an outgrowth from the brain, and the rods and cones point inward. In the cephalopods the entire eye is formed by an infolding of the ectoderm (outer layer of the skin), and the rods and cones point outward. These two fundamental differences indicate that the eyes have been developed independently in the two phyla.

Teacher's Demonstration.—Illustrate image formation by holding a white cardboard near a convex lens (a reading glass will do) and securing an image of the window or some object outdoors. Note that the image is inverted and smaller than the object.

The appearance of various invertebrate eyes may be demonstrated by passing specimens from the museum case around the class.

A diagram of the human eye may be put in the notebook.

22. THE NERVOUS SYSTEMS OF ANIMALS

How are the activities of the parts of the body controlled?

PROTOZOA and PLANTS have no nervous system, yet we have shown that plants are *irritable*,—*i.e.*, they are able to respond to a stimulus, and that protozoans are composed of a single cell the functions of which are general; each cell being able to perform such functions, as digestion, locomotion, respiration, and sensory activity, which are delegated to special cells in the higher animals.

STARFISH.—The nervous system in the higher animals is either *radially* or *bilaterally symmetrical*. In the radially symmetrical starfish the alimentary canal is the axis of the animal, and all parts are arranged around this. The nervous system consists of a *nerve ring*, which is really a pentagon, surrounding the mouth region. At each of the five angles of the pentagon a nerve tract is given off to each arm. It runs along the lower side of the arm and gives off branches to all parts of the member. It terminates at the end of the arm in a sensory organ called an *eye*.

"The starfish is a fairly successful representative of a somewhat unprogressive biological principle. It has greatly elaborated the radial type of symmetry, and represents, with other echinoderms, the highest degree of specialization along such lines. That the

radial arrangement of body parts has some things in its favor can not be disputed. It is certainly advantageous to be able to move with equal facility in any direction. It is desirable to be able to take food or receive notice of danger on any side of the body.

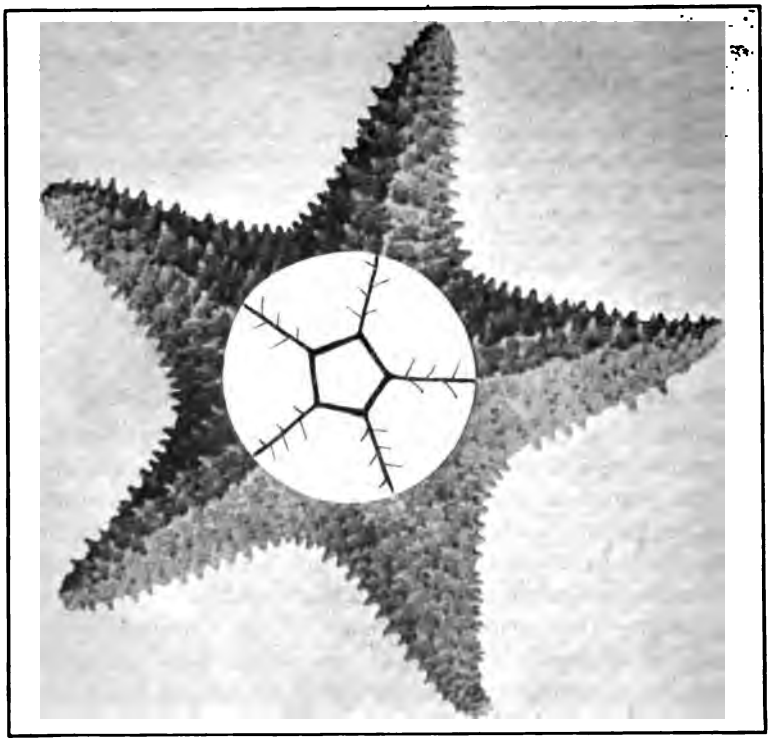


FIG. 134.—Photo-diagram of the nerve ring of a starfish. The esophagus passes through the center of the pentagon.

"But usually the disadvantages more than compensate for the favorable features associated with radial symmetry. As was pointed out in connection with the cœlenterates, it is hard for a radially symmetrical animal to correlate its abilities for a particular end. A starfish has five arms bearing five equally important sets of sense organs (eyes, tactile tentacles, etc.) and what little power

of attention it has must vacillate between these or be continually divided. This is important because the development of higher physical processes (memory, power of attention, reason, etc. as they appear in animals with well-centralized nervous systems) depends upon seriously attending to one thing at a time." (Pearse, *General Zoology*)

The BILATERALLY SYMMETRICAL animals are of two forms so far as the nervous system is concerned. The invertebrate types have a *ventral* nervous system, and the vertebrate types have a *dorsal* nervous system,—*i.e.*, the nerve cord lies in the under side of the body, or in the back.

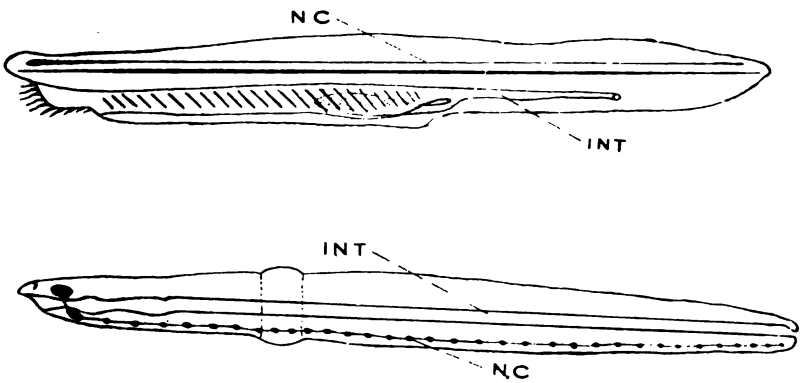


FIG. 135.—Two diagrams to illustrate the difference in the position of the nerve cord in invertebrates and vertebrates. The one above is based on amphioxus, and the one below is based on the earthworm. Note that in the earthworm the intestinal tract is above the nerve cord and in amphioxus it is below. *INT*, intestine; *NC*, nerve cord.

THE EARTHWORM has in its head, above the pharynx, two nerve knots or *ganglia*, sometimes called the *brain*, united together by a nerve tract or *commissure* (Lat. *commitere* = to join together). (See Fig. 95.) From them, extending downward and backward, a pair of tracts pass on either side of the pharynx and unite beneath to form a ganglion. This is the first of a series of double ganglia which extend along the ventral side of the body throughout its entire length. The entire series is linked together by a pair of nerve cords, and resembles a ladder in form. From each ganglion,

branches radiate to the parts of the body which are near by. The nerves running to the upper lip (*prostomium*) are especially abundant. The "brain" and chain of ganglia constitute the *central nervous system.* The branches to the body constitute the *peripheral* (surface) *nervous system.*

The peripheral nerves are of two types,—those that carry nervous impulses in to the central system and those that carry them out. The nerves running in to the central system are known as *sensory nerves.* Those that run out are mostly connected with muscles and control movement, therefore they are called *motor nerves.*

The nervous system of the earthworm is typical of all invertebrate, segmented animals. The arthropods,—such as insects, centipeds, and spiders are of a higher order than the earthworm and have a more elaborate nervous system, but it is built on the same plan. There is a tendency for the ganglia to be moved forward toward the thorax so that the ganglia do not coincide with the segments, and in some forms the thorax ganglia are fused into a single mass. This facilitates nervous control.

AMPHIOXUS is of great interest to zoologists because it represents the type of central nervous and skeletal systems that was probably possessed by the primitive vertebrates. A rod of cartilage runs from the head to the tail of the animal, and dorsal to this, the nerve cord runs. It is simply a bundle of nerve cells and fibers that forecasts the spinal cord in the higher vertebrates. An enlargement appears at the anterior end of the cord. Consult the diagram and understand fully the fundamental differences between the nervous systems of the earthworm and amphioxus.

THE FROG has a distinct skull cavity containing a brain which may be divided into three main divisions: *forebrain*, *midbrain*, and *hindbrain*. The forebrain is composed of two *cerebral hemispheres* and two *olfactory lobes*, each of which receives a nerve (*olfactory nerve*) from the smelling organs (*olfactory organs*) in the nose cavity. The midbrain is composed principally of the *optic lobes*. They are very large in proportion to the rest of the brain and lie above the *optic chiasma* where the nerves from the eyes cross. The hindbrain is composed of the small *cerebellum* and the *medulla*.

IN MAN the cerebrum is greatly enlarged and extends forward and

backward over the greater part of the rest of the brain. The olfactory lobes are small and the optic lobes are divided into *four bodies* (*corpora quadrigemina*). The cerebellum is also enlarged and lies beneath the back part of the cerebrum. The brain is flexed above the medulla so that the long axis of the cerebrum is at right angles to the medulla, whereas in the frog they are parallel.

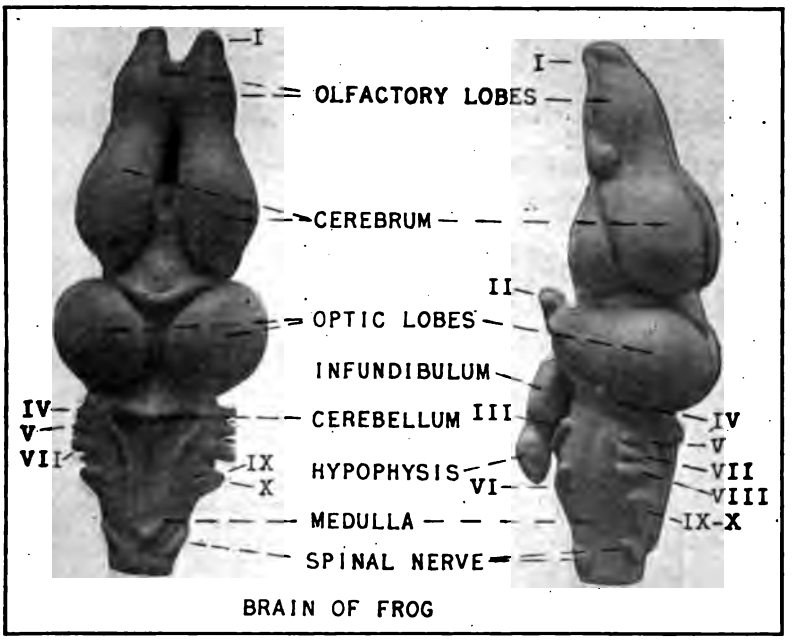


FIG. 136.—Two views of the frog's brain. The dorsal surface is shown on the left and the view from the left side is shown on the right. The cranial nerves are labeled *I* to *X*. (*From photographs of Ward's models.*)

The medulla is continued down the back, dorsal to the vertebral column, as the *spinal cord*. It is about seventeen inches long and about three-fourths of an inch thick. It is nearly cylindrical but somewhat flattened dorso-ventrally and tapers toward the lower end. Fissures run along both the dorsal and ventral sides of the cord and nearly divide it. A cross section of the cord shows that it

is composed of white fibers and gray cells. The fibers are situated around the outside, and the nerve cells are in the center of either half and form a band across the middle.

CRANIAL NERVES.—In man twelve pairs of cranial nerves leave the skull through openings in its base. The first pair arise from the olfactory lobes and are known as the *olfactory nerves*. The second pair arise from the optic chiasma of the midbrain and carry sensations of sight to the brain. The others leave the hindbrain and are listed in the table below.

TABLE OF THE CRANIAL NERVES AND THEIR DISTRIBUTION

I. **Olfactory,** from olfactory bodies.
II. **Optic,** from retina of eye.

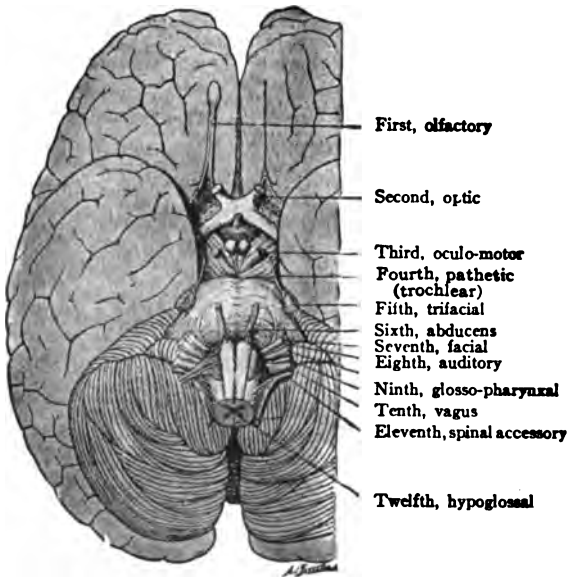


FIG. 137.—Ventral view of the brain of man to show the cranial nerves. (*From Bundy, after Monat and Doyen; Brubaker.*)

III, IV, VI. **Eye motor nerves,** to eye muscles.
V. **Trigeminal,** to and from various parts of the head.

VII. Facial, to and from the face.

VIII. Auditory, from the ear.

IX. Glosso-pharyngeal, to and from the tongue and pharynx.

X. Vagus, to and from the gullet, stomach, larynx, lungs, and heart.

XI. Spinal accessory, joins the vagus, and to shoulders.

XII. Hypoglossal, to and from the tongue.

SPINAL NERVES.—Thirty-one pairs of spinal nerves join the spinal cord. Each divides before reaching the cord, into a dorsal

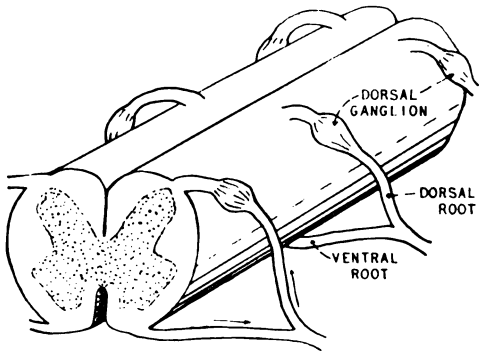


FIG. 138.—Sterogram of the spinal cord to show how the spinal nerves are attached. Note that the dorsal nerve has a ganglion and the ventral one does not. Note that the cord is nearly divided into a left and right half by a narrow, deep, dorsal fissure and a broad, shallow, ventral one. The distribution of the gray matter in the middle of the cord is shown in stippling.

and ventral branch called *posterior* and *anterior roots*. The posterior branch always contains a ganglion. The ventral branch does not. Impulses travel in over the dorsal branches and out over the ventral ones.

Plaster of Paris models of the starfish, amphioxus, the earthworm, and frog may be secured from Ward's Natural Science Establishment, Rochester, N. Y. They are of value to show some of the features discussed in this study. Brain models of the shark, frog, and man may also be obtained to show their parts and the cranial nerves.

23. INSTINCT, HABIT AND INTELLIGENCE

How are the brain and nervous system related to the habits and activities of the individual?

Each part of the brain has its special work to do. If a part be removed, its work can not be done. *If the entire brain of a frog is removed* and its spinal cord is left intact, it lies flat on its belly instead of supporting its body with its fore legs as does the normal frog. However, its hind legs are drawn up under its flanks in a natural

FIG. 139.—Two photographs of the leopard frog posed to show the normal position which the animal assumes when at rest and the prostrate position assumed when the brain has been removed.

way. The muscles in the walls of its arteries are relaxed, and it does not breathe. If a hind leg is moved the proper muscles contract and it is pulled back into position. If the skin is irritated along the side of the body the frog will make an effort to remove the irritation, but it does nothing unless it is stimulated.

If the cerebrum and cerebellum are removed, the frog maintains the same position as before; but the muscles of the blood system function, and respiration goes on.

If the cerebrum only is removed and all other parts left undisturbed, the frog sits erect. If its position is changed it maintains its equilibrium by crawling or turning over. It can be made to croak, and if thrown into water will swim. If it comes into contact with the bank it will crawl out and come to rest. It acts very much like a normal frog under stimulation, but it does practically nothing without stimulation, and does not vary its responses, —*i.e.*, it always gives the same response to the same stimulus no matter how many times it is repeated. If the lips are touched the animal tries to remove the irritation with its fore foot. It seems to be incapable of making any other response. The normal frog might try this method once or twice but would soon find another way to remove or escape from the annoyance. Animals without their cerebrums act like mere machines.

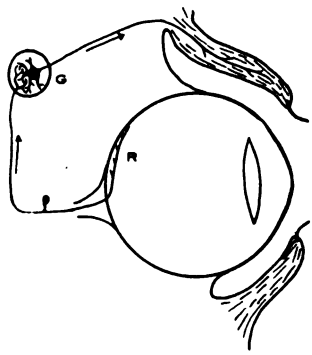


FIG. 140.—Diagram of the eye to illustrate the nervous control of the reflex of winking. If an object is coming toward the eye, the nerves in the retina *R* will send an impulse to the ganglion *G* where it will be directed to the motor nerve fibers which run to the muscles of the eyelids, causing them to contract and close the eye. Other nerve fibers carry the impulse to the brain, but the wink has taken place before the brain has had time to react.

Reflex Action.—The acts which are performed by the frog without a complete brain are known as *simple reflex acts* and have been mentioned before in connection with the earthworm. *A simple reflex act is one that is performed as a result of an external stimulus and without conscious effort.* The individual may, however, become aware of the act after it has been performed.

Automatic Acts.—The muscular action which attends respiration, circulation, and digestion is not the direct result of an external stimulus, and hence these acts are not reflex. Such acts are, however, performed without conscious effort and are called *automatic* acts.

Habitual acts such as chewing, walking, talking, and riding a bicycle have to be learned; but after they are learned they can be performed without conscious effort. They are the result of practice and are called *habitual acts*. When these acts are first performed considerable mental effort is required, and they are very imperfect. Finally, they become more perfect and can be performed with less attention of the higher mental powers. Thus the cerebrum is relieved of their control which passes to the lower centers in the medulla and cord.

Habit.—The lower animals live largely by reflexes; but as we ascend higher in the scale of animal life we find animals with more highly developed nervous systems, depending more and more upon habits for their body control. It is surprising to note how completely our lives are dominated by habits which may be good or bad. We arise in the morning, dress, eat our meals, and go about our daily tasks with very little thought about what we are doing. Most habits are formed in early life, and they grow constantly stronger as we become older. Therefore it is of the greatest importance that we exercise the most care possible to form good habits of thought and conduct in the habit-forming period of our lives.

"The hell to be endured, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkel, in Jefferson's play excuses himself for every fresh dereliction by saying, 'I won't count this time!, Well! he may not count it, and a kind Heaven may not count it; but it is being counted none the less. Down among the nerve cells and fibers the nerve cells are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become

saints in the moral, and authorities in the practical and scientific spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he keep faithfully busy each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."—James, *Psychology*.

Instinct.—A large percentage of the acts of animals are controlled by *instinct*. Birds do not have to learn to build nests. Nest building, incubation, and care of the young are instinctive acts. A hen that was hatched in an incubator and raised in a brooder will make just as good a mother the next season as one that has had the experiences of parental care. The social instincts of ants, bees, and wasps are very highly developed and can sometimes be slightly modified by the individual. M. Fabre, in experimenting with a digger wasp (*Sphex*) which preys on grasshoppers and always drags them into its burrow by seizing them by the antennæ, found that the wasp was able to drag the locust in by seizing the jaw appendages when the feelers were cut off, but could not sufficiently modify her instinct so as to seize a fore leg when the jaw appendages were also removed.

FIG. 141.—A pair of purple martins. Have you observed anything in their behavior which would indicate that they prefer any special kind of box? What type of box is most attractive to them?

The purple martin and the tree swallow offer a good example of the modification of an instinct by birds. They formerly built their nests in hollow trees and cavities in rocks. Now the purple martin prefers the bird boxes of boys to any other abode, and the tree swallow is often found nesting in such boxes, but its instincts have not so completely changed as have those of martins.

Intelligence.—An animal's intelligence may be measured by its ability to overcome or modify its instincts when special conditions arise. Intelligence involves memory and the ability to profit by experience. From this point of view the intelligence of all invertebrate animals is very low. Among the lower vertebrates, frogs and fish are capable of learning by experience, but only to a very limited extent. Fish may remember the location of a plate of glass in water after bumping into it several times.

"No fish is ever conscious of himself; he never thinks of himself as doing this or that, or feeling in this way or that way. The whole direction of his mind is outward. He has no language and so can not think in verbal terms; he never names anything; he never talks to himself. As Huxley says of the crayfish, he 'has nothing to say to himself or anyone else.' He does not reflect; he makes no generalizations. All his thinking is in the present and in concrete terms. He has no voluntary attention, no volition in the true sense, no self control." (Professor Sanford, quoted by Linville and Kelly, *General Zoology*.)

Reason.—Acts which are performed in accordance with a plan which takes into account both the means to be employed and the end to be achieved may be said to be *rational*. If you wish to cross a stream, you may consider the possibility of crossing on foot, by raft, swimming across, or going around by way of a bridge. After considering the various possibilities a course of action is chosen, and the stream is crossed. This is a very simple example of reason. Although many scientists doubt the ability of animals to reason, a few believe that dogs and some other animals are capable of choosing between two courses of action to accomplish a purpose. Reason is the most complex faculty of the mind and is the most important mental advance of man over the lower animals.

Debate.—A laboratory period may be devoted to a debate on the subject "Resolved that some animals can reason."

Social Recitation.—Give the members of the class a chance to relate their personal observations of animal intelligence.

Make a list of some of the habits which your school mates have and which can be corrected. Avoid personalities.

24. THE EFFECT OF POISONS ON LIVING TISSUE

What are poisons, and how do they act on the human system?

ALKALOIDS are substances which are elaborated in plant tissues. They resemble alkalies in that they form salts with acids,—hence the name. They substitute themselves for important parts of the living protoplasm, and thus destroy it. The actions of these substances are, however, very diverse.

Caffein is found in tea and coffee. It has a stimulating effect on parts of the brain. In large and concentrated quantities it is dangerous, and in small quantities is a habit former. *All alkaloids*

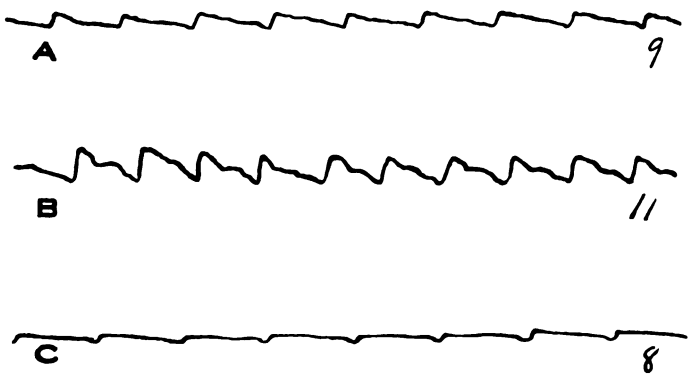


FIG. 142.—The effect of tobacco on the heart beat. *A* is a graph made by a normal heart. *B* is by a heart after the subject had smoked a cigarette. Note that the beat is faster, and stronger, and less steady. *C* is the graph made by a person who has lost vitality by excessive smoking. The pulse is weak and slow. The ratio of the three cases is 9 : 11 : 8.

are habit formers. Their continued use so disorganizes the nervous system that it can not carry on its normal functions unless the drug is present. This sets up a craving, and makes it difficult for one who has become addicted to their use to get along without them.

Theobromine is found in chocolate and cocoa. It does little harm in the small quantities in which it exists in these foods as ordinarily used.

Nicotine is found in tobacco. It is a violent poison when taken even in small quantities. As has been stated before, three drops of

pure nicotine is sufficient to kill a normal man. The ill effects of the use of tobacco, especially by boys, is too well known to require proof. "Human experience shows that the unwise use of tobacco may unfavorably affect digestion, cause serious disorders of the heart, and impair the work of the nervous system. Those training for athletic events are usually forbidden the use of tobacco because it 'takes the wind,'—*i.e.*, makes impossible the most efficient training of the heart. Many employers have found that youths who smoke cigarettes are less reliable in their work; and this is only one instance of the effect upon the nervous system already referred to, the same result being observed in a diminished steadiness of the hand, often amounting to actual tremor.

"Especially to be condemned is its use by those who have not attained their full growth. During youth nothing should be allowed to interfere with the best development of the heart and nervous system, and the use of tobacco endangers the proper development of both of these most important parts of the human mechanism. It can hardly be doubted that many a young man has failed to make the most of life because the habit contracted in his youth has struck in this way at the foundations upon which he had subsequently to build." (Hough and Sedgwick, *The Human Mechanism.*)

Codein, morphine, and **laudanum** are made from opium which is extracted from the opium poppy. These alkaloids deaden the nerves and are, therefore, used to relieve pain. *They do not remove the cause of the pain but merely relieve the suffering of the patient.* Because of this their use often becomes a habit which is very difficult to break. The physical, mental, and moral life of the victim is greatly impaired. When without the drug the user becomes mentally deranged and suffers all the horrors of the insane until relieved by more of the drug. Opium victims are not wholly responsible for their acts and can not be trusted.

Quinine is made from the bark of the cinchona tree. It is a valuable medicine, because its presence in the blood destroys the germs of malaria. It should not be used as a drug. *Cocaine* is obtained from the leaves of coca and is used to deaden pain. *Strychnine* is obtained from the seeds of *Strychnos nuxvomica,* a tree which grows in the East Indies. It is a violent heart stimulator

and a deadly poison. Besides these there are many other less known alkaloids.

ANESTHETICS produce sleep. **Ether** and **chloroform** are examples. They are of inestimable value in modern surgery. They cause unconsciousness, but their action on nervous tissue is not fully known. They are fat solvents and it has been suggested that they may dissolve out fat from the protein substances in nervous tissue. This has not been proven, however.

MINERAL POISONS.—If a soluble salt of silver, mercury, or lead is placed in the white of an egg, coagulation occurs; and the mass becomes white and opaque. The heavy metals are capable of combining chemically, from solutions of their salts, with the living protein molecule. When bichloride of mercury is swallowed the white of an egg is given as an antidote. Why?

Workmen in lead and mercury industries are often poisoned by these metals. Recent researches have shown that the young of animals which have been fed lead acetate in small quantity show an appreciable decrease in size and vitality. A large proportion of the young are born dead. These results hold, even when only the male receives the poison. Phosphorus affects the workmen in match factories, causing the bones to decay and the teeth to fall out. Children born of parents so affected often die in infancy, and those that live are handicapped by decreased vitality. Matches can be made by using red phosphorus or phosphorus sesquisulphide, neither of which is poisonous. The manufacture of yellow phosphorus matches is now prevented by a prohibitive tax, and their exportation is forbidden.

HEADACHE POWDERS usually contain some chemical,—such as *acetanilid* which acts as a heart depressor. "It has long been known that acetanilid, antipyrin, and phenacetin are habit-forming drugs particularly acetanilid. The habit is usually acquired through the use of the remedy without the supervision of the physician for the relief of minor aches and pains, especially headache. Troubles of this kind are peculiarly likely to return again and again, and the remedy has but a temporary effect; hence the dose must be repeated, and in time the patient may become dependent upon the drug. Furthermore, the ache or pain for which the medicine was first

taken is often worse than ever after the effects of the remedy have passed away, because of the weakened condition of the system which

FIG. 143.—Two rabbits from the same litter, bred by Professor L. J. Cole, University of Wisconsin. The father of the white rabbit was fed a small amount of lead with his meals. The father of the black one was normal. Note that the white one is only about half as large as the black one. Similar results were obtained by Dr. Chas. R. Stockard by feeding alcohol to the male parent. (*Journal of Heredity.*)

may result from the use of these agents, and hence there is additional call for the remedy. Thus a habit may be established—more drug,

impaired bodily health, lessened resistance, more pain, more drug." (Kebler, Morgan, and Rupp, *U. S. Department of Agriculture, Bulletin* 377.)

ALCOHOL.—If the white of an egg is placed in a test tube and a strong solution of alcohol is placed on it, it will coagulate. (This result is not obtained with a weak solution.) Alcohol kills protoplasm by coagulating it,—*i.e.*, it draws the water out and at the same time hardens it. Its action is both physical and chemical. If strong alcohol is taken into the system in considerable quantity death results.

"The evil effects of alcohol are so continually demonstrated upon man that there is no need for experimental investigations to establish this fact. Pathological examination of the tissues in the case of confirmed drunkards has demonstrated the existence of definite lesions in many of the organs,—stomach, liver, heart, nervous system,—and have shown that under these conditions it acts as a tissue poison.

"Regarding its stimulating action the general experience of mankind attributes a result of this kind to its use in small quantities, but the experimental evidence is of an uncertain nature. Some observers have claimed that the reaction time is diminished after the use of alcohol, but most of the recent investigation goes to show that in the work of skilled labor, in which the neuromuscular machinery is involved, alcohol even in small quantities decreases the efficiency. It has been suggested, therefore, that as regards the higher nerve centers, it acts from the beginning as a narcotic or paralysant to the inhibitory centers. By thus removing inhibitory control there is an apparent increase in activity which is not due to a direct stimulating effect." (Howell, *Physiology*.)

The removal of inhibitory control destroys judgment. For this reason the partially intoxicated man talks freely and often wittily but more often foolishly. In cases of excessive drinking the victim becomes more irrational, stumbles, falls, and passes into a drunken stupor. If this is repeated often a complete breakdown of the nervous system sets in, and even when sober the man appears to be unbalanced. He finally becomes a raving maniac and thinks he sees all sorts of snakes and horrible creatures. This is the climax

of continued intoxication and is called *delirium tremens*. It often ends in death.

Many people believe that alcohol gives warmth to the body. Professor Howell says, "It is known that even in small doses it causes a dilation of the skin vessels, giving a feeling of warmth and leading to increased loss of heat." This fact has long been known by arctic explorers who universally condemn the use of alcohol on their journeys. Dr. Brunton is authority for the following account:

"A party of engineers were surveying in the Sierra Nevadas. They camped at a great height above the sea level, where the air was very cold, and they were chilled and uncomfortable. Some of them drank a little whiskey, and felt less uncomfortable; some of them drank a lot of whiskey, and went to bed feeling very jolly and comfortable indeed. But in the morning the men who had not taken any whiskey got up in a good condition; those who had taken a little whiskey got up feeling very miserable; the men who had taken a lot of whiskey did not get up at all: they were simply frozen to death. They had warmed the surface of their bodies at the expense of their internal organs." (From a quotation by Peabody and Hunt, *Elementary Biology*.)

"The capital argument against alcohol, that which must eventually condemn its use, is this, that it takes away all the reserve control, the power of mastership, and therefore offends against the splendid pride in himself or herself, which is fundamental in every man or woman worth anything." (Walt Whitman.)

Teacher's Experiment.—Place some egg white in five test tubes. Treat one with a soluble salt of mercury, another with a soluble salt of lead, another with a soluble salt of silver, heat one, and treat the other with strong alcohol. Prepare another set and treat them with various strengths of alcohol.

The student should understand that the protoplasm was destroyed in the above tests. What is a poison? Why is egg-white an antidote for the poisons mentioned above?

UNIT IV. PROBLEMS OF GROWTH AND REPRODUCTION

25. THE LIFE HISTORY OF THE AMEBA AND ITS ALLIES

How do single celled animals grow and multiply?

PROTOZOANS are single celled animals. The majority of them are free-living, but some are parasitic. They are found in both salt and fresh water, and are exceedingly abundant. Although, all

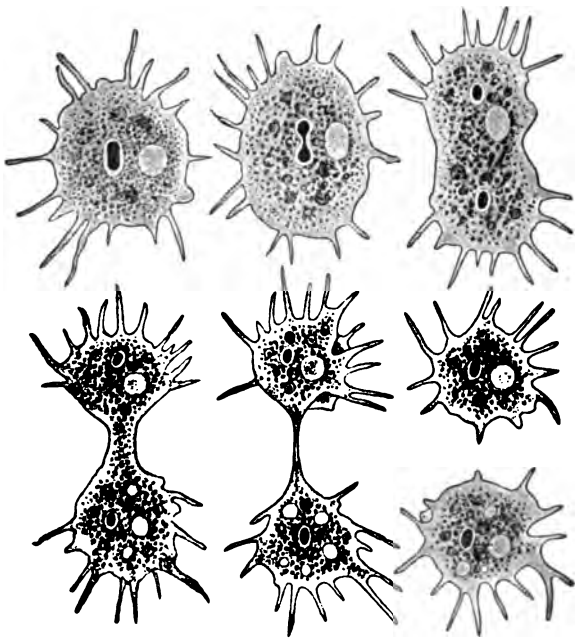


FIG. 144.—Six drawings of an ameba to show how one divides. Note how the nucleus separates and how the cytoplasm pulls apart. (*From Marshall, after Schulze and Lang, after Doflein.*)

living forms are microscopic in size, a marine fossil (*Nummulites*) has been found which had a diameter of two inches. We have previously mentioned some of the responses of ameba, euglena,

and paramecium. In this study we will use two of these types to illustrate the phenomena of reproduction in the protozoans.

Ameba.—In many ways ameba is the simplest of the protozoans. It lives in the mud or on the surface of objects in ponds. It can be raised in the laboratory by placing some pond weeds in a dish of water and allowing them to decay. The amebas can usually be found on the sides of the glass jar or in the scum which forms at the top of the water.

In feeding, an ameba puts forth processes called *pseudopodia* (false feet) which flow around the food particle and thus take it into the body. It is surrounded with a fluid, the digestible parts are absorbed, and the remains cast out. Material may enter or leave the body at any place.

Respiration is carried on through the entire body-surface. When the ameba grows to a certain size (about $\frac{1}{100}$ of an inch) it is no longer able to properly supply its body through its surface. This is because, as the animal grows, the volume increases as the cube of the diameter, and the surface only as the square. Thus the surface is no longer able to absorb enough oxygen to maintain the life of the ameba. The solution of this difficulty is the division of the animal into two equal parts. Each part becomes an independent individual one-half the size of the parent.

Reproduction.—When division takes place the nucleus divides and each part migrates to an opposite side of the cell. As this is taking place a constriction occurs around the cell so that it assumes a dumbell shape for a time before finally separating.

The protozoans have been said to be immortal,—*i.e.*, they never die a natural death, but continue to divide and live on forever if not killed. However, it is doubtful if division could go on forever if it were not for a process called *conjugation* which takes place after an ameba has passed through many divisions. In conjugation two individuals come together. Their bodies fuse and each receives a portion of the nucleus of the other. Conjugation has been said to be a *rejuvenating process*,—*i.e.*, the old ameba has its youth restored. All amebas produced by the first few divisions after conjugation are looked upon as *young;* later they all become *mature*, and finally after many divisions they all become *old*. Thus an ameba is young

or old throughout its entire life. The old ones conjugate, restore their youth and vigor and begin another series of divisions.

Problem.—Starting with one young ameba, how many would there be after ten divisions? After twenty divisions?

Scheel describes another method of reproduction in ameba called *sporulation*. The pseudopodia are drawn in, the animal becomes a sphere, and a heavy case is secreted around it. Movement may be observed within the case for several days; then the nucleus begins to divide. It passes through several divisions, and five or six hundred nuclei are formed, each surrounded by a bit of protoplasm. Finally the case breaks open, the spores escape and grow within a few weeks to mature amebas.

When the pond in which amebas live dries up they encyst themselves and remain inactive until favorable conditions are established, when they emerge from their cysts and begin an active life again. This explains why it is that amebas may be found in ponds that dry up in the summer.

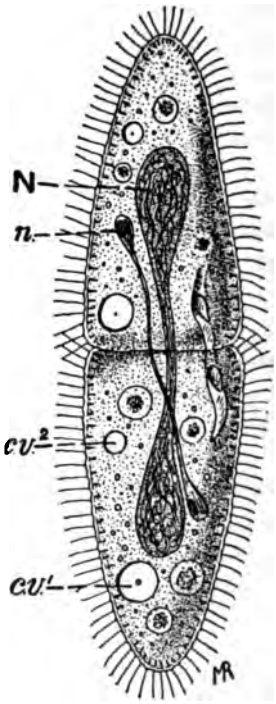


FIG. 145.—Transverse division in Paramecium. *N*, macronucleus; *n*, micronucleus; *cv*, contractile vacuoles. (*From Marshall, after Minchin.*)

Paramecium is more highly specialized than ameba. It has a definite shape, a definitely located mouth, and the waste material always leaves the cell at a definite point. Pseudopodia are not formed, but the animal is covered with hair-like processes called *cilia*. They are movable and are used to propel the animal through the water and draw food particles to the mouth cavity.

Project.—Large numbers of paramecia may be raised in the laboratory by placing hay or dry grass in jars containing water and adding a little pond-water, or water from an aquarium. In about two weeks they may be seen as tiny white specks collecting near the surface of the water.

Paramecia reproduce by division. They are not known to reproduce by any other method. There are two nuclei in paramecium,—one large one called the *macronucleus* and a small one called the *micronucleus*. The large one probably controls the activities of the cell, and the small one has a very important part to play in reproduction. In division both nuclei divide and migrate toward opposite ends of the animal, and then the cell divides transversely. Division usually takes place once or twice a day and is completed in about two hours after the first stages are observable.

Conjugation in paramecium differs from that of ameba in that it is temporary instead of permanent. When two paramecia conjugate each receives some of the nuclear material of the other, whereupon they separate. The nuclear material of each individual then fuses to form a single nucleus in each. This nucleus then divides forming two nuclei; then by two more divisions eight are formed, at which time two divisions of the cell take place which leaves two nuclei (a macronucleus and a micronucleus) in each of the four offspring. This is a bit complicated. Can you make a diagram to illustrate it?

If it is true that the nucleus controls the cell, then the identity of each paramecium is double (duplex) from the time of conjugation on. It is probable that conjugation has much to do with heredity as we will explain later.

Plasmodium.—Protozoans of the genus *Plasmodium* are the cause of malaria. There are at least three species causing three kinds of malaria in man. *Plasmodium malaria* causes a chill every seventy two hours, and *P. vivax* produces a chill every forty eight hours. Other forms are parasites in other animals, especially birds.

We will attempt only a brief outline of the life history of *Plasmodium*. If a mosquito which has malaria bites a person, worm-like cells, called *blasts* (Fig. 146, 1), enter the blood with the saliva which is injected by the mosquito to prevent the blood from coagulating. These blasts bore into a red corpuscle and take on an ameboid form (2). This ameboid cell forms many spore cells which nearly fill the corpuscle and cause it to cease functioning (3). This causes the chill. The corpuscle breaks, and the spores escape together with the poisonous waste products of their metabolism (4). This poison causes the fever. These spores may enter other red corpuscles to

repeat the process and cause another chill in forty eight or seventy two hours (5); or some of them may be sexual cells which will conjugate if they are taken up in a red corpuscle by a mosquito (6). The female cell becomes rounded, and the male cell assumes a spindle shape. Conjugation between these cells takes place in the stomach of the mosquito (7). An elongated cell results (8). It bores into the stomach wall and forms a cyst (9). In about two weeks the

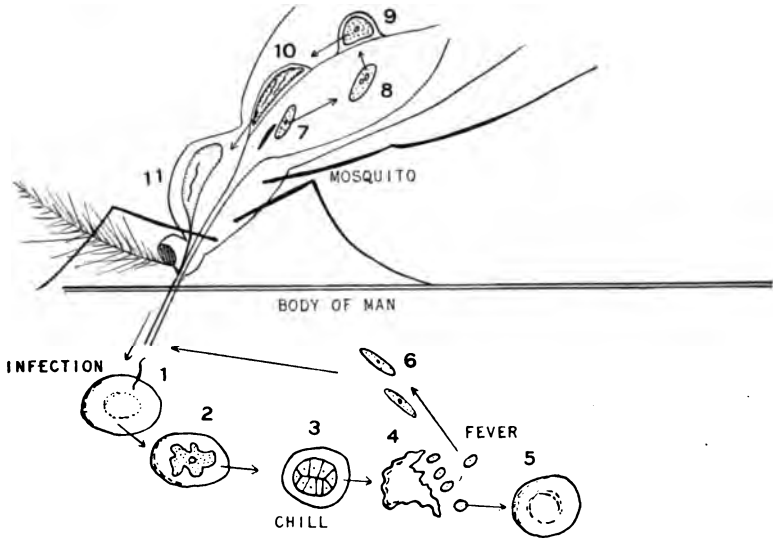


FIG. 146.—Diagram of the life history of *Plasmodium*, to show its relation to man and the mosquito, and how it causes a chill and fever.

cyst is greatly enlarged and filled with a great number of long, slender, but very minute blasts (10). They emerge into the body cavity and make their way to the salivary glands (11), and thus enter the blood of the next person attacked by the mosquito. If large doses of quinine are taken so that it is present in the blood when the spores are released from the red corpuscles (4) they will be killed and the disease cured.

Laboratory Suggestions.—The protozoans may be studied alive by means of the microscope, from charts, or from models. It may be possible to secure a moving picture reel showing some of them in action. If your lantern has a

microscope attachment the living forms may be projected on the screen by placing them in a cell on a glass slide before the lens.

A diagram of the life history of *Plasmodium* may be put in the student's notebook.

26. THE LIFE HISTORY OF ALGÆ

How do the simplest plants grow and multiply?

ALGÆ are the simplest plants which possess chlorophyll and are capable of making starch, and thus are able to live an independent life. They are found in moist places or in water. Some of the forms which live in the ocean are rather complex in structure. Algæ may be divided into four classes as follows:

I. **Blue-green.** Ex. *Gleocapsa.*
II. **Green.** Ex. *Pleurococcus, Spirogyra, Ulothrix, Vaucheria.*
III. **Red.** Mostly marine forms.
IV. **Brown.** Mostly marine forms.

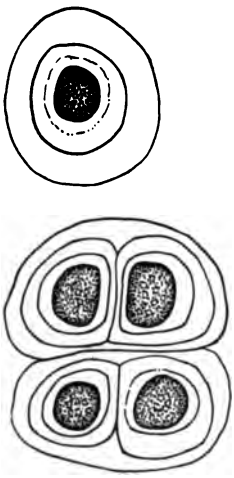


FIG. 147.—Gleocapsa, a single cell above and a group of four below, showing the method of multiplication.

Gleocapsa is a single celled alga of the first class. The cells are spherical and of a pale blue-green color. They are grouped in colonies and are covered with a jelly-like envelope which holds them together. The cell structure is very simple; the green matter being distributed evenly throughout the cell, and no nucleus can be seen, except after staining. Gleocapsa lives in water that is stagnant and on objects in damp places.

Reproduction takes place by a simple division of the cell into two equal halves. This process is called *fission*. Later the old gelatinous envelope disintegrates, and the two cells may separate; but more often the cells remain within the old envelope; and sometimes accumulate in colonies containing eight or sixteen cells. No other method of reproduction is known. If the water dries up, they go into a resting condition and become active again when conditions are favorable.

Pleurococcus belongs to the green algæ. It is the green coating found on old tree trunks, fence posts, and similar situations. It is a single cell and has no gelatinous envelope as has gleocapsa. The cells are composed of an outer wall surrounding a green body called a *chloroplast* which is suspended in the protoplasm of the cell and nearly fills it. It is variable in size and contains a dense portion called a *pyrenoid*. (Pyrenoids have not been discovered in the blue-green algæ.) A distinct nucleus may be seen in the center of each cell of pleurococcus.

Reproduction takes place by cell division very much as in gleocapsa. In some near relatives of pleurococcus which live in the water, an additional method of reproduction occurs. Several small cells may be formed within the wall of the parent cell. The old cell wall breaks and the daughter cells escape. Each is provided with two small hair-like lashes called *cilia* (singular, *cilium*). These wave in the water and enable the young cells to swim. After a time they come to rest, lose their cilia, and become like the parent cell. Special cells which are formed in this way and are capable of developing into a plant like their parent are called *spores* (Gr. *spora* = seed). If they are able to swim, they are called *zoöspores* (Gr. *zoön* = an animal). Algæ which produce swimming spores have a better means of distribution than those that reproduce by fission only. Thus we see that pleurococcus and its allies are more complex in both structure and methods of reproduction than the blue-green alga, gleocapsa.

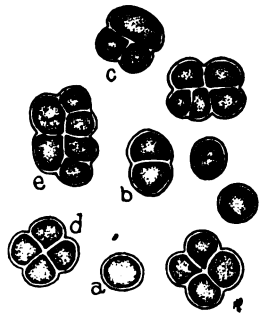


FIG. 148.—Pleurococcus, to illustrate its method of division. (*From Gager.*)

Spirogyra is a green alga also, but of a more complex type than pleurococcus. It may be found in ponds and in slow flowing streams in great abundance in summer, either floating or entangled with weeds and grass. It often forms great masses of green slime in stagnant ponds. The cells are cylindrical and are attached together end to end, forming *filaments*. This condition is the result of the method of cell division which is always in parallel planes. The

cells divide transversely, and thus the length of the filament is increased. (See Fig. 184.)

The chloroplasts are spiral bands of chlorophyll extending throughout the length of the cell. The number of bands differs in different species, and there are several pyrenoids in each band. The nucleus is large and may be seen without staining.

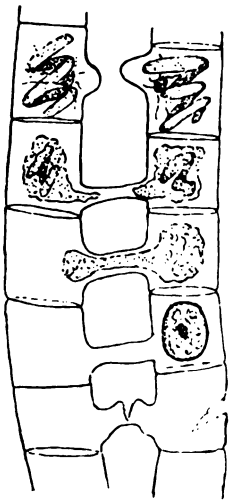


FIG. 149. — Two filaments of spirogyra in conjugation. The first four pairs of cells show how the zygospore is formed.

Nutrition is carried on by absorbing carbon dioxide, salts, and oxygen from the water by osmosis. The chloroplasts function the same as the green tissue of the higher plants, manufacturing starch. Each cell makes its own food, and is independent, in this respect, of the other cells of the filament.

Conjugation.—We have studied the process of conjugation in paramecium in the previous study. A somewhat similar process takes place in spirogyra. At times tubes are put forth from the sides of cells in filaments which lie close together. The tubes from two cells unite end to end and fuse as shown in the figure. This tube forms a passageway between the two cells. The contents of one cell pass through the tube and fuse with that of the other leaving one cell empty. This mass of protoplasm from both cells goes into a resting condition and produces a thick outer wall for protection. When conditions are right, it germinates; and by cell division it produces a filament like one of the two from which it came.

In conjugation in spirogyra the two conjugating cells are apparently alike, and the fusion is complete and permanent. The resting spore thus formed is called a *zygospore* (Gr. *zygon* = a yoke + spore), and the two cells which unite are called *gametes* (Gr. = husband or wife). This method of producing a spore is said to be *sexual* because there is a union of protoplasm from two different cells.

Ulothrix is a filamentous alga similar to spirogyra, but the chloroplasts are not in spiral bands. Like spirogyra, it reproduces both

sexually and asexually; but the method of forming the spores is different. The asexual spores are formed somewhat like those of certain relatives of pleurococcus,—*i.e.*, several zoöspores are released

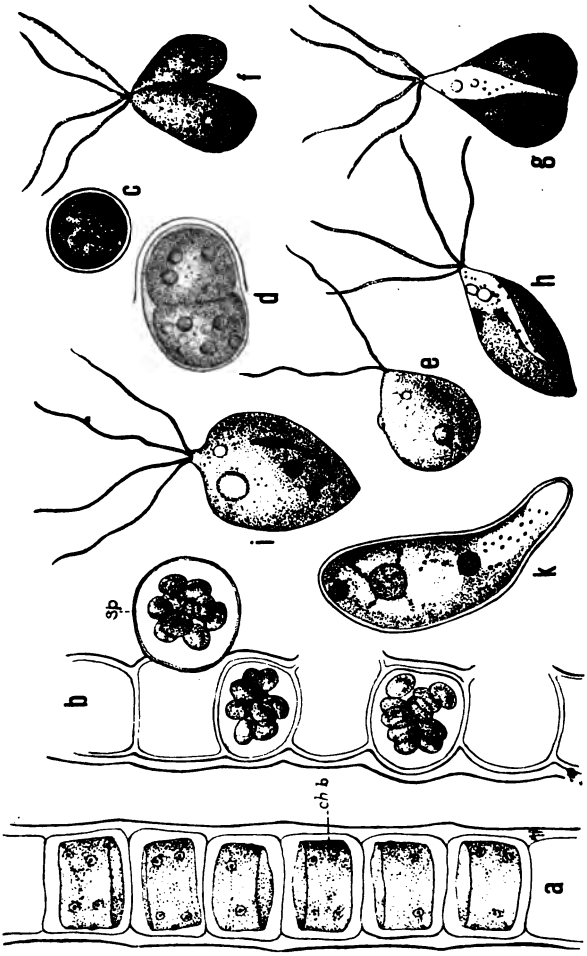


FIG. 150.—Various stages in the life history of ulothrix. *a*, a filament showing the chlorophyll bodies (*ch b*); *b*, a filament from which either gametes or zoöspores (*sp*) are escaping; *c*, a zygote formed by the fusion of two gametes; *d*, beginning of germination of the zygote; *e*, gamete; *f*, conjugation of like gametes; *g*, *h*, completion of the conjugation; *i*, zoöspore; *k*, germinating zoöspore. (*From Gager after Oltmanns.*)

from a single parent cell. These zoöspores possess four cilia and resemble euglena very much, even to the red eye-spot; and mark the nearest approach of the plant and animal kingdoms to each other.

After swimming around for a time, they settle down and produce another filament like the parent.

In sexual reproduction similar cells are produced in large quantities. They are smaller than the zoöspores and possess only two cilia. They are gametes and can not reproduce the parent type until two of them have conjugated. For some time after conjugation the zygospore which now has four cilia like the asexual spore, but two red eye-spots, swims around and grows. It finally develops four asexual zoöspores which emerge from the parent spore case and grow to reproduce the plant. The union of two gametes of equal size and structure is called *isogamy* (Gr. *isos* = equal + *gamos* = marriage).

Vaucheria (Pro. vâ-kē′-ri-ä) is a filamentous alga which may be looked upon as having lost the dividing walls of its cells which make

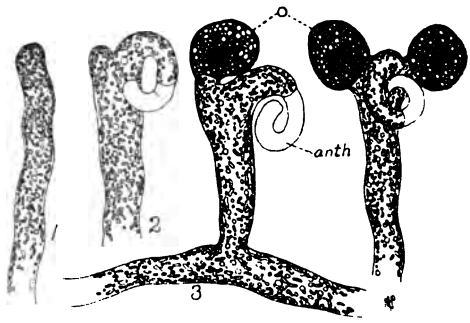


FIG. 151.—The reproductive organs of Vaucheria. *anth*, the empty antheridium where the sperms are produced; *o*, two oögonia each containing an egg. (*From Gager.*)

up the filaments, thus making the filament a continuous tube filled with chloroplasts and containing many nuclei. Such a filament is called a *cœnocyte* (Gr. *kinos* = common + *cytos* = a cell). In sexual reproduction, processes grow out from the side of the filament. One type of structure is large and sac-like; the other is long, coiled, and tube-like. The large structure contains but one large gamete, and is called an *oögonium* (Gr. *oön* = an egg + *gonos* = offspring). The large gamete is called an *egg*. The tube is called an *antheridium* and produces many small, two-ciliated gametes called *sperms*. A sperm fuses with an egg and fertilizes it. It then becomes an *oöspore*

(egg spore), and may reproduce the plant. Fertilization differs from conjugation only in that the gametes which fuse are of unequal size, and an oöspore differs from a zygospore in the same particular. When gametes are of unequal size the condition is spoken of as *heterogamy* (Gr. *heteros* = other than or different + *gamos*) in contradistinction from *isogamy* where the gametes are alike. Discuss the advantages of each type of reproduction.

Field Trip.—Make collections of algæ from a pond. Pleurococcus may be collected from tree trunks. Make aquaria and keep the specimens in the laboratory. What animals did you find living among the algæ? Some of the specimens should be observed under the microscope or projected on the screen by the lantern. What forms require much light? What forms little? Do the forms which you put in the jars stay there or are they superceded by other forms? Do goldfish eat algæ?

If living material showing the various types of reproduction can not be found, preserved material can be had from dealers. Specimens showing conjugation, isogamy, and heterogamy may be permanently mounted on microscope slides.

27. THE LIFE HISTORY OF MOSSES

How do mosses reproduce their kind?

In the previous study we have traced the development of the reproductive processes in the algæ from *fission*, through *spore formation*, to the development of *gametes* which conjugate; and finally to the development of *heterogamy*. In the present study we will consider a more advanced type of reproduction known as *alternation of generations* in which an asexual spore producing plant gives rise to a sexual spore producing plant, which produces the asexual plant again. Thus, we have two kinds of plants and two kinds of spores in each life history.

Moss plants grow erect in close formation in all sorts of situations. They are found in barren fields, on the roofs of houses, in bogs, on old logs, and in the water. Although they are found in a great variety of situations, they always grow where the struggle for room is not intense. Thus, they avoid competition with the higher plants.

The moss plant shown in Fig. 152, on the right, is really two plants. The lower part is leafy and is called the gametophyte (a

plant producing gametes). The upper part is adapted for the production of asexual spores and is called the *sporophyte* (a plant producing spores). The sporophyte grows on the gametophyte and gets its nourishment from it. It may be looked upon as a parasite on the gametophyte from which it arises.

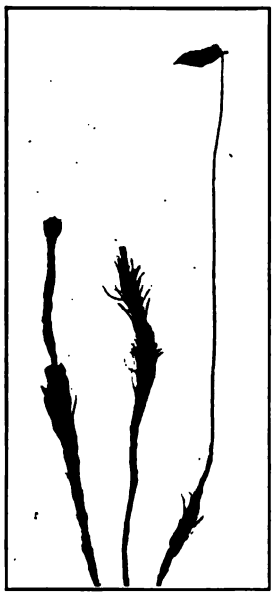


FIG. 152.

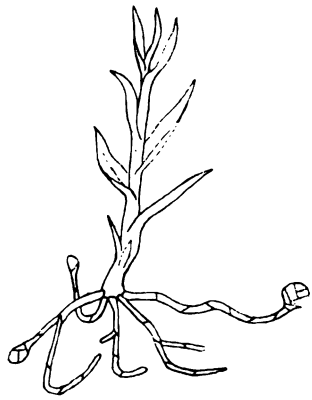


FIG. 153.

FIG. 152.—Three moss plants. The one on the left is a male with a second year's growth springing from the crown of the year before. The one in the center is a female. The one on the right is a female bearing a sporophyte.

FIG. 153.—A young moss plant growing from filaments of protonema. The buds on the filaments will produce other young plants.

In tracing the life history we will begin with one of the asexual spores produced in the capsule at the upper end of the sporophyte. The asexual spore germinates and produces a branched filament similar to that of the algæ, but differing from the algæ filaments in that the cross walls are oblique. It is called the *protonema* (Cr. *protos* = first + *nema* = thread). It forms a felt-like mat on the surface of moist soil. Some of the cells at the ends of branches

become swollen and later divide to form a several celled *bud* (Fig. 153). Its resemblance to the buds of higher plants is only superficial, but from it the erect stem of the moss grows.

The leaves of the moss have no resemblance to the leaves of the higher plants except in external appearance. They are arranged spirally around the stem and are composed of flat cells joined together by their edges so as to form a tissue one cell layer in thickness, excepting along the midvein of the leaf where there is a doubling of the layer. Fibrovascular tissue is not found in either the leaf or the stem of the moss plant. Its absence causes the flow of cell sap to be slow and limited. For this reason the moss plants can not lift themselves far above the source of mosture.

Sex.—Moss plants are usually of two kinds,—male and female. The male plants produce sperms, and the female plants eggs. The sperms are produced in many celled, club-shaped structures called *antheridia* (Gr. *antherose* = flowery) (Fig. 154). They are borne on the top of the male plants among peculiar, sterile structures called *paraphyses*. In the presence of sufficient moisture the antheridia swell, the tips break open, and the sperms escape. They are able to swim actively by means of their two cilia.

The eggs are borne in flask-shaped structures called *archegonia* (Gr. *arch'e* = first + *gonos* = race). They are found on the top of the female plant (Fig. 154). An egg is developed in the base of the archegonium and when it ripens the neck becomes a hollow tube down which a sperm may swim to fertilize the egg. The egg is retained in the base of the archegonium after being fertilized and develops into a long, slender structure,—the *sporophyte*. One end of this structure grows down into the base of the archegonium and comes into intimate contact with the cells in the upper part of the moss plant. This part is called the *foot*. It serves to anchor the sporophyte to the moss plant, and at the same time it absorbs food. The other end of the sporophyte develops into a slender stem called a *seta* (bristle) and bears a capsule at its upper end. The remains of the old archegonium usually remain as a *caliptra* (hood) on the upper end of the capsule. Beneath the caliptra is a lid, the *operculum*, and beneath this is a ring of triangular teeth which close the opening to the inside of the capsule.

Asexual spores are produced in the capsule by fission. In many forms they are distributed by the action of the teeth which are sensitive to moisture; curling in when moist and out when dry, thus distributing the spores in dry weather. The spores germinate under proper moisture conditions and produce the protonema with

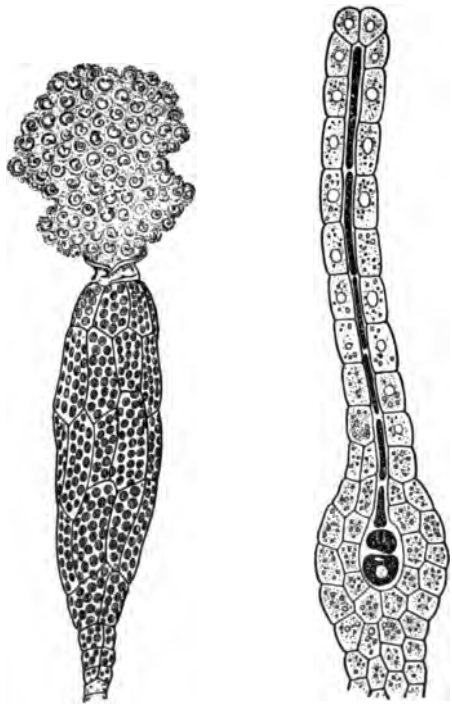


FIG. 154.—An antheridium and an archegonium. Sperms are shown issuing from the top of the antheridium. An egg is shown at the base of the archegonium. The long black cells in the neck of the archegonium will disintegrate and form a passage for the entrance of a sperm. (*From Berghen and Davis after Sachs.*)

which we started this life history. We may sum up the history in a formula as shown on the opposite page.

Evidences of an alternation of generations are found in some of the higher algæ and fungi, but these cases have no relation to the alter-

nation of generations in the mosses and liverworts. It was developed in this group independently and has been preserved by all the higher plants which have developed from the mosses, and in each division above the bryophytes the process has become more complex as we shall see later.

Conjugation was developed by both the protozoa and algæ, and probably is of advantage to plants and animals in *preserving the vigor of the species* and *as an aid to variation.* It is believed that the characters of the offspring from two parents will be more apt to vary than will the characters of offspring from one parent only. If the conditions under which a plant lives change slowly the characters of the

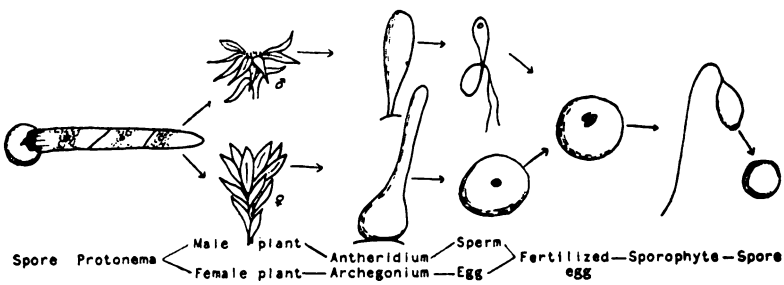


FIG. 155.—Diagram of the life history of a moss plant.

plant must change to meet the new conditions. If they can not do this the plant will perish in that locality. At any rate, the eggs of nearly all plants and animals are fertilized, and some very complex habits and structures have been developed to facilitate the process; hence, it is believed to be very essential; but biologists still have much to learn about the necessity of conjugation.

Heterogamy was developed by the algæ in order that food for a more rapid development might be stored in the zygospore; and it is more convenient to have it stored in one of the two gametes, and have the other one of a small size and produced in large quantities. This makes swimming through the water safer and fertilization more certain.

The advantages of alternation of generations are not so apparent in the mosses, but as we shall see later, sperms always reach eggs

by passing through a liquid medium, and it is difficult to provide for this in the case of land plants except by alternating a sexual and an asexual generation. It would be almost impossible for sperms to pass from one fern frond to another, or from the top of one tree to another, through water. This air journey is made by the asexual spore which does not swim. This matter will be made clear in the next two studies.

Field Trip.—Make a collection of mosses. Dry and mount some of the choice specimens for the museum cases. Make a list of the situations in which you find mosses growing.

Project.—Will some one try to raise moss plants in the laboratory? The air of the room will be too dry for them. They must be kept under glass in a moist atmosphere.

Laboratory Work.—The entire life history of each of the four groups of plants may be worked out from preserved material, charts, and microscope slides; but probably all students may not care to do this work.

28. THE LIFE HISTORY OF FERNS

How do ferns reproduce their kind?

Ferns are found in many parts of the earth. They grow in dry fields, in deep woods, and in deserts; but it is in the tropics that they reach their greatest luxuriance. The *tree ferns* of the tropical forests may grow to a height of forty feet. Here *epiphytic ferns* have abandoned the habit of growing on the ground and live on the branches of trees. The moist tropical air supplies them with water, and they get their mineral food from the decaying bark and débris which accumulates about their roots.

The roots and stems of our ferns do not rise above the ground. The leaves are borne on long leaf-stems and are called *fronds*. Some of them may be especially modified to bear spores and do little or no photosynthetic work. These are called *sporophylls* (Gr. *spora* = seed + *phyllon* = leaf). (See Fig. 156.)

The great advantage that ferns have over mosses is that they possess *fibrovascular tissue*. This makes the development of roots and a stem possible, and permits the sap to flow readily from one part of the plant to another. The roots and stems of ferns are, however, not so well developed as those of the flowering plants; and

for this reason they either grow where the competition is not severe, or have developed the ability to live in the shade of forest trees.

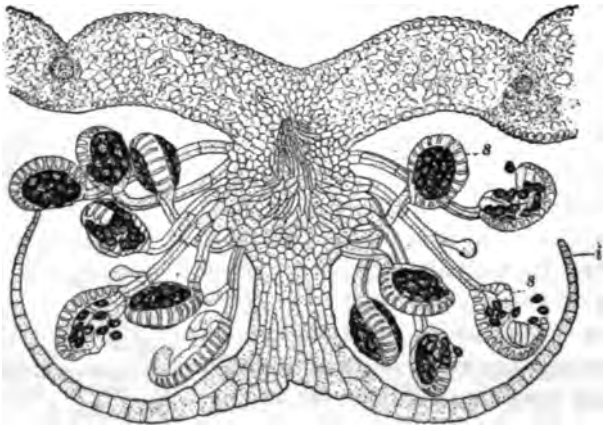
In the moss the gametophyte or sexual phase of the life history is the most prominent. In the fern the sporophyte is the prominent phase, and the gametophyte is seldom seen, and is unknown to most people. The sporophyte of the fern has overcome its dependence upon the gametophyte and developed roots, a stem, and leaves as have the flowering plants; but it still reproduces by spores as do the moss plants.

The spores are usually borne on the fronds or sporophylls in cases called *sporangia* (Fig. 158). They may be attached in groups and covered with a fold of the edge of the leaf, or by a special structure developed for the purpose and called an *indusium* (Lat. *induere* = to put on). This indusium, together with the sporangia grouped under it, is called a *sorus* (pl. *sori*) which comes from the Greek and means a heap (Fig. 157).

The sporangia are discus-shaped structures borne on stalks. Around the edge, on one side, is a row of enlarged and thickened cells called the *annulus* (ring). See Fig. 158. When the spores are ripe the spore case opens on the side opposite the annulus; and by expanding and contracting under varying moisture conditions, the annulus lifts up the top of the spore case with some of the spores adhering to it. It is then snapped shut and the

FIG. 156.—The adder's tongue fern, showing an underground stem (*r*), a frond (*l*), and a sporophyll (*sp*). (*From Gager.*)

FIG. 157.—An "*x-ray*" picture of two leaflets of the Boston fern, made by exposing a piece of photographic paper through the leaflets. The sori are seen as white spots on the leaf to the left.



[redacted] 158.—Diagram of a section through a sorus, showing the indusium (*i*), and [redacted]e sporangia (*s*). (*From Berghen and Caldwell, after Engel and Prantl.*)

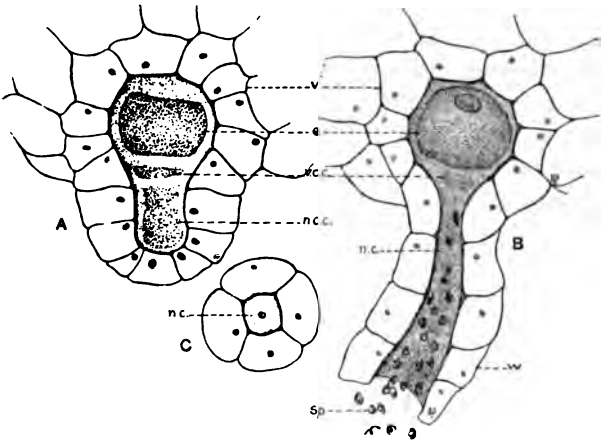


FIG. 159.—Development of the archegonium of the fern. *A*, young archegonium; *B*, mature archegonium with sperms entering its neck; *C*, tip of archegonium. *v*, base of archegonium (venter); *e*, egg; *v.c.c.*, ventral canal cell; *n.c.*, neck-canal; *sp*, sperms. (*From Gager.*)

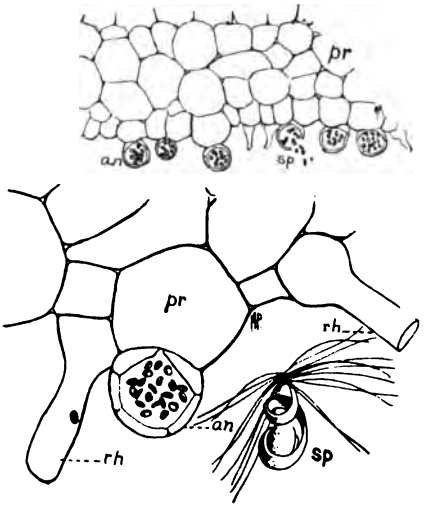


FIG. 160.—The antheridia of the fern are shown above attached to the lower surface of the prothallus. Below is a greatly enlarged drawing of an antheridium (*an*) and a sperm (*sp*). Rhizoids are lettered *rh*. (*From Gager.*)

spores are thrown out. This is a means of spore distribution. The spores, however, are not thrown very far and all species do not possess the annulus on their sporangia. Compare this method of ejecting spores with that of the moss.

If a spore falls in a moist place it may germinate and develop into a scale-like, green structure which clings to the ground and sends rhizoids into it for salts and water. It is called the ***prothallium*** (Lat. *pro* = before + *thallus* = branch). It is usually heart-shaped, less than one half inch in diameter, and but one cell in thickness except in the middle. It has no roots, stem, or leaves and bears sperms and

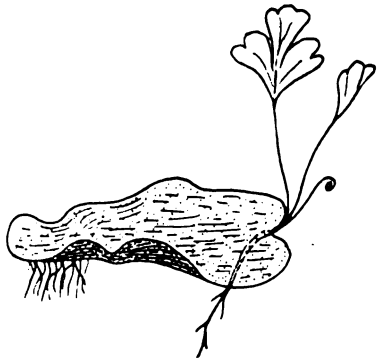


FIG. 161.—A young fern plant growing from a prothallium. Note the difference in the nature of rhizoids and roots.

eggs. In these respects it resembles the gametophyte of the mosses and liverworts, and is the gametophyte generation in the life history of the fern. Fern gametophytes may often be found in greenhouses in moist places where ferns are kept. They may be raised in the laboratory by placing the spores of ferns on moist sand and keeping them covered with glass to prevent evaporation.

The archegonia and antheridia are rather degenerate structures and are found on the under side of the prothallium. Sperms and eggs are produced as in the moss, but the sperms are more complex in structure. They vary in different species, but in some forms they consist of a ribbon with a spore on one end and a group of long, slender lashes at the other (Fig. 160). A sperm swims to an egg

in an archegonium and fertilizes it. The egg then develops and puts forth into the tissue of the prothallus, a foot which functions for a time; but soon a root and shoot are formed, and the young sporophyte becomes independent. In this the fern differs from the moss where no root or shoot is formed.

For review compare the life history of the moss and the fern in all details. Compare the illustrations carefully. Do florists propagate ferns by alternation of generations?

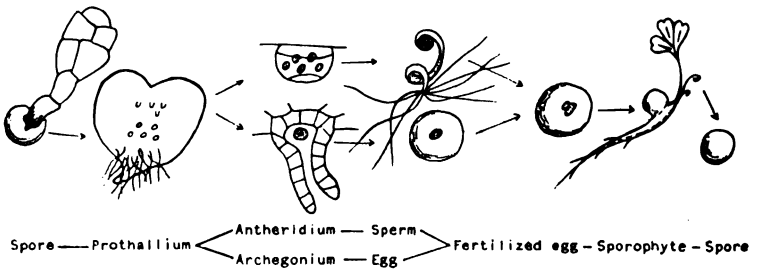


FIG. 162.—Life history of the fern.

Project.—Try to raise some ferns from their spores.

Laboratory Work.—The life history of the fern may be studied from charts, lantern slides, microscope slides, and actual material.

29. THE LIFE HISTORY OF THE PINE

How do pines reproduce their kind?

The seed producing plants are divided into two groups—the GYMNOSPERMS (from the Greek meaning naked seeds) or cone bearing plants, and the ANGIOSPERMS (from the Greek meaning having a vessel for seeds) or flowering plants. We will study the pine as a type of the gymnosperms.

In passing from the ferns to the pines it is interesting to mention an intermediate type,—*Lycopodium* which bears cones but no seeds. In so far as it bears cones it resembles the pines, but in so far as it bears spores and no seeds it resembles the ferns, near which group it is placed in botanical classification.

The pine reproduces by an alternation of generations as do the mosses and ferns, but the fact that it produces two kinds of asexual

spores makes the life history more complex. The smaller spores are called *pollen grains* and are blown by the wind from the cones where they are formed to the cones containing the other sort of spores which are larger and germinate in the cones where they are produced.

FIG. 163.—A lycopod, or club-moss, which bears its spores in cones. This species is abundant in the northern part of the United States.

The two kinds of spores are produced in separate cones which differ in size. The smaller ones are called *staminate cones* and produce pollen. The larger are called *carpellate cones* and ultimately bear the seeds. The pollen is produced in sacs in great quantity on the under side of the scales of the staminate cone. It should be kept in mind that the pollen grains are spores. They are

called *microspores* because they are the smaller of the two kinds. The sacs in which they develop are called *microsporangia.* Upon reaching the carpellate cone the pollen grain develops into a degenerate gametophyte (pollen tube) which produces sperms but no eggs.

The carpellate cones bear large spores called *megaspores* at the base of the cone scales in sacs which are *macrosporangia.* The

FIG. 164.—Male cones of the Austrian pine. Those above have shed their pollen. (*From Gager.*)

scales of pine cones are modified leaves which bear spores and, hence, are called *sporophylls* as in ferns. Megaspores also develop into degenerate gametophytes which produce eggs but no sperms, hence, the terms *male* and *female* are applied to the spores and cones of the pine. Since the pollen grains are spores and not sperms the trees that bear them are not sexual but belong to the asexual phase of the life history which is the sporophyte generation.

While the pollen is being shed the carpellate cones stand upright and spread the tips of their scales so as to catch the pollen which is

distributed by the wind. It settles down to the base of the scales where the megaspores are produced. Originally the pollen grain contains a single nucleus, but this nucleus divides several times in the development of the gametophyte. However, no cell walls are built around the separate nuclei. Soon after arriving at the base of the scale on the carpellate cone a tube-like process called the *pollen tube* grows from the pollen grain and slowly dissolves its way

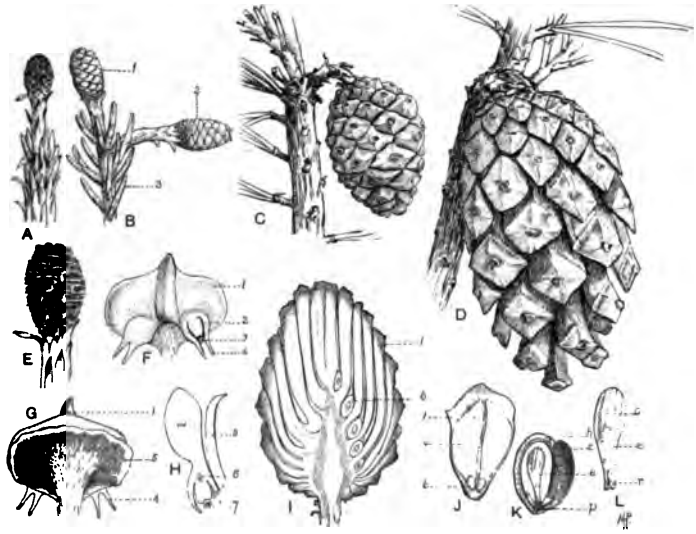


FIG. 165.—Carpelate cones of the Scotch pine. Scotch pine (*Pinus sylvestris*). *A—D*, stages in the development of the carpellate cone, and its carpotropic movements. *E*, very young carpellate cone much enlarged; *F*, ventral, *G*, dorsal views of a scale from *E*; 1, ovuliferous scale; 2, ovule (in longitudinal section); 3, pollen chamber and micropyle leading to the apex of the nucellus (megasporangium); 4, integument of the ovule; *G*, 1, tip of ovuliferous scale; 5, bract; 4, integument; *H*, longitudinal section at right angles to the surface of the ovuliferous scale (diagrammatic); 6, megaspore; 7, pollen-chamber; *I*, longitudinal section of a mature cone; 6, ovule; *J*, scale from a mature cone; 6, seed; *w*, wing of seed; *K*, dissection of mature seed; *h*, hard seed coat; *c*, dry membraneous remains of the nucellus, here folded back to show the endosperm and embryo; *e*, embryo; *p*, remains of nucellus; *L*, embryo; *c*, cotyledons; *e*, hypocotyl; *r*, root-end. (*From Gager.*)

through the tissues which surround the developing megaspore. The pollen tube corresponds to an antheridium in the mosses and ferns, and when mature it contains four nuclei, two of which are sperms.

After pollination the carpellate cone reverses its position and hangs down. Its scales now shed water like the shingles of a roof. The megasporangium in which the megaspore is borne is fleshy and is called the *nucellus*. It is situated on the upper surface of the

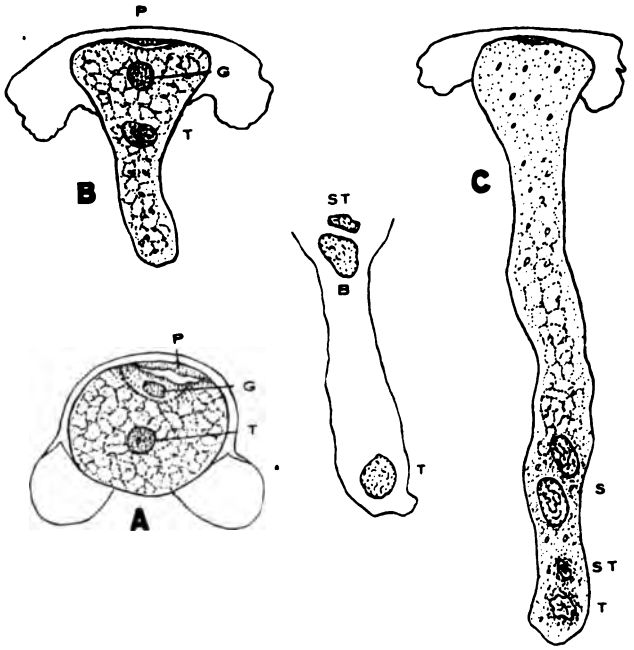


FIG. 166.—The development of the pollen tube. In *A* the pollen grain is shown containing prothallial cells (*p*) against the side of the pollen grain. They have been budded off before the grain was shed. The tube nucleus (*T*) has been divided off from the generative nucleus (*G*).

In *B* the tube has been put forth and the tube nucleus has moved down into it. Between the stages represented in *B* and *C* the generative nucleus has divided to form a stalk and a body nucleus (*ST* and *B*).

In *C* four nuclei are present in the pollen tube,—the tube nucleus (*T*), the stalk nucleus (*ST*), and the two sperm nuclei (*S*). The sperm nuclei have been produced by a division of the body cell which, for this reason, has disappeared and is not shown in *C*.

scale of the carpellate cone, and is surrounded by an *outer* and an *inner integument* both of which help to form the seed coats of the ripe seed.

The megaspore nucleus divides many times and the separate nuclei ultimately have cell walls built around them, so that this gametophyte is cellular. It grows to a relatively large size and is called the *endosperm* (Gr. *endo* = within + *sperma* = seed), and corresponds to the vegetative portion of the prothallium of the fern. Thus, we see that the production of two sizes of spores in the pines is accompanied by the production of two kinds of cones and gametophytes. It may be noted here also that both the pollen tube and

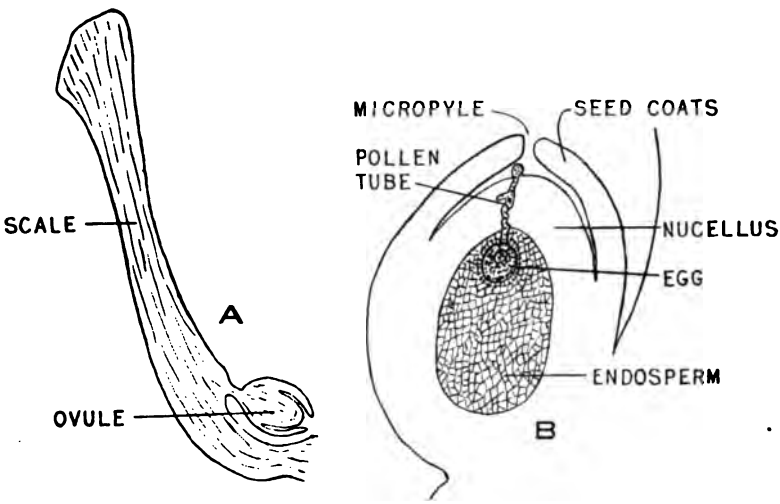


FIG. 167.—The female gametophyte of the pine. *A*, a scale of the female cone at the time of pollination. The ovule contains a megaspore (not shown). *B*, the ovule at the time of fertilization. The endosperm is the female gametophyte, and the pollen tube is the male gametophyte. Note that the cone has reversed its position so that the ovule opening points upward.

the endosperm have lost their chlorophyll and become parasitic upon the carpellate cone.

In the spring, a year after pollination, several archegonia, each bearing a very large egg, are formed in the gametophyte and are supported by the endosperm. Shortly after this the end of a pollen tube reaches a newly formed archegonium. It fuses with the egg membrane, and its four nuclei are discharged into the egg. One of the sperms fertilizes the egg nucleus, and the other three cells

disappear. The egg then begins development and ultimately produces an *embryo* or young sporophyte which lies embedded in the endosperm from which it draws nourishment. It grows to a certain size and then partly dries and passes into a resting condition which is the *seed*. The essential advance here over the fern is that the growth of the embryo is checked, and a seed is formed. This does not occur in the ferns, where when the embryo once starts its growth it continues to grow. A pine seed, then, is an embryo sporophyte embedded in the gametophyte and surrounded by seed coats formed from part of the pine cone. How many generations are present in the pine seed?

A pine seed requires two years for its development, and some pines hold their seeds many years before shedding them from the cones. The seeds usually bear a wing and are distributed by the wind. Secure a pine seed, and let it fall to the floor, and see it spin.

Summary.—The advances which the pines have made over the ferns are as follows:—

1. Two kinds of spores are produced. This condition is called *heterospory* (Gr. *heteros* = other + spore). You will recall that heterogamy was established in the algæ and persists throughout the higher groups. Heterospory enables plants which live on land and are tall to maintain a sexual phase with sperms which pass through water or some liquid. The male gametophyte (pollen grain) is brought to the female cone in pollination, and the pollen tube establishes the contact with the egg, and the sperms are passed direct from the pollen tube to the egg nucleus. Plants have been unable to produce sperms which can pass through dry air. They are always found in a liquid medium.

2. The two gametophytes have lost their chlorophyll and live, parasitically on the carpellate cone. They are greatly degenerate and scarcely form antheridia or archegonia. The number of sperms has been reduced from many to only two. Why?

3. The growth of the embryo is interrupted and a seed is formed which may preserve the life of the species over winter or a dry spell, and which is easily distributed to great distances, and may germinate and grow under comparatively adverse conditions.

4. The sporophyte (pine tree) is a more efficient type of life than the fern plant.

The four advances may be briefly stated as, the development of heterospory in addition to heterogamy, the degeneration of the gametophyte, the production of the seed, the improvement of the sporophyte generation.

The life history of the pine may be expressed by the following formula:

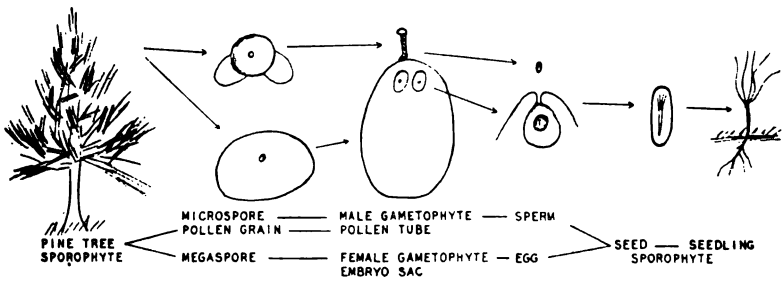


FIG. 168.—The life history of the pine.

Review.—Compare this with the one given for the moss and note the effect of heterospory on the formula.

Museum Project.—Make a collection of the various kinds of conifer needles and cones, label them, and save for future reference.

Laboratory Study.—The gametophytes and their nuclei may be observed from prepared slides which can be purchased from any of the leading supply houses.

30. THE FLOWER AND POLLINATION

What part does the flower play in the life history of seed-plants?

The complete angiosperm flower consists of six parts: pedicel, receptacle, calyx, corolla, stamens, and pistil. Fig. 169 is a diagram of a complete flower. The essential structures are the stamens and pistil, and the flower is said to be *perfect* if it has these, whether the calyx and corolla are present or not.

The parts of the *calyx* are arranged in a circle and usually consist of three, four, or five green, leaf-like structures which protect the bud before it opens, and are called *sepals*. The showy part of the

flower is the *corolla* which is usually colored and corresponds in number of parts and arrangement to the sepals. It is more apt to vary

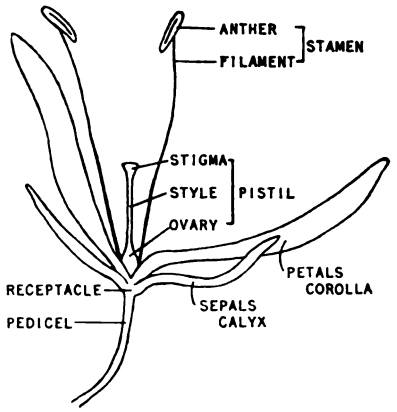


FIG. 169.—Diagram of a flower to show its six parts and their subdivisions.

than the calyx, however, and is often a double circle or may not be symmetrical as we shall see. Its parts are called *petals*. They may

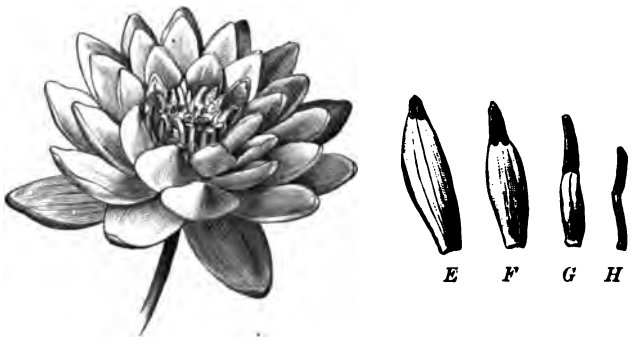


FIG. 170.—Water lily showing a gradual transition from sepals to petals and to stamens. Note that some petals bear anthers on their tips. (*From Berghen, and Davis, after Brown.*)

be more or less united together to form a tube,—as in the morning-glory, gourd, pumpkin, four-o'clock, and flax.

The stamens are also arranged in one or more circles and bear the pollen (microspores). They correspond to the pollen bearing scales of the pine cone and are microsporophylls. Each stamen usually consists of two parts: a *filament* and an *anther*. If the anther is attached directly to some part of the flower and no filament is present it is said to be *sessile*.

The pistil, when mature, bears the seeds and is composed of one or more parts called *carpels*. The carpels correspond to the scales of the seed-bearing pine cone and are megasporophylls. They inclose one or more cavities called *locules*. The seeds are attached to definite areas (*placentas*) of the walls of the locules. A normal pistil is composed of three parts: The base which contains the carpels is called the *ovary;* a moist or feathery surface for the reception of pollen is called the *stigma;* and a part connecting the ovary and stigma is called the *style*. If the stigma is attached directly to the ovary, it is said to be *sessile*.

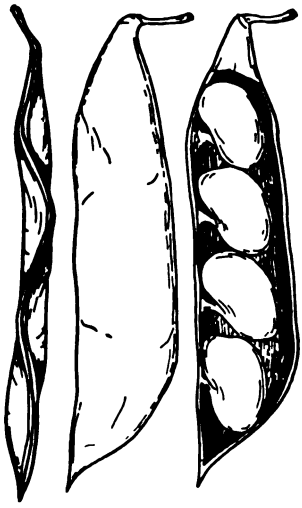


FIG. 171.—Bean pod is an example of a fruit in which the carpels still resemble leaves from which they were originally derived. (*From Robbins.*)

Sepals, petals, stamens, and carpels are modified leaves serving the function of reproduction. The transition from sepals to stamens is gradual in the water lily, a flower of many circles; as is shown in the figure. The carpels of almost all flowers have suffered greater change than any other parts, but still retain a leaf-like appearance in the pea pod, milkweed pod, and the columbine.

Classification.—We have learned before that all flowering plants may be divided into two great classes. They are the MONOCOTYLEDONEÆ, the flower circles of which usually have three parts, and the DICOTYLEDONEÆ, the flower circles of which have four or five parts. If some wild flowers are available, count their sepals and petals and decide to which class they belong. In many domestic flowers the arrangement has been modified by breeding. See Fig. 212.

Pollination.—The pollen which is produced in the anther must be carried to the stigma of the same flower (or as is more often the case to the stigma of another flower of the same species) or the seeds can not form. Pollen is carried in three ways: namely, by *water*—in the

FIG. 172.—The pistillate flower of corn. The silks are the stigmas which are adapted for wind pollination. (*From Robbins.*)

case of a few water plants, by the *wind*, and by *insects* or other flower-visiting animals. Flowers which do not have showy petals have feathery or spreading stigmas and are dependent upon the wind for carrying their pollen. Grains, grasses, and sedges are examples.

We will now consider a few of the many modifications which the flowering plants have taken on to facilitate insect pollination. Geologists tell us that flower-inhabiting insects and flowers with showy petals were developed contemporaneously in ancient times. Each group is dependent on the other for existence. The showy petals and perfume aid insects in finding flowers. Practically all flower visiting insects can distinguish colors and have a well developed sense of smell. The nectar which is secreted by glands near the base of the pistil serves as food for many insects. Thus, we see that *color*, *perfume*, and *nectar* have been developed in flowers in connection with pollination.

FIG. 173.—Cleistogamous flowers of the violet. 1, a bud; 2, a flower; 3, a seed capsule; 4, an open seed capsule. This is the common blue violet. The flowers were produced indoors, in the fall of the year, and were not buried as they are in some violets.

In spite of the fact that much study has been given to the subject, the advantages and disadvantages of *cross pollination* (the transfer of pollen from the stamens of one flower to the pistil of another of the same species) are not very well understood. The problem is complicated by the fact that many flowers, such as those of wheat normally fertilize themselves,—*i.e.*, pollen is transferred from the stamens to the pistil within the same flower. This is called *self-pollination*.

Some plants produce flowers which never open and are consequently self-pollinated. In the violet they are produced after those

that open and are often subterranean. One of the milk worts (*Polygala polygama*) bears both open and closed flowers at the same time. The closed ones are beneath the surface of the soil. *Lamium*, a mint, produces closed flowers in the spring and fall, and open ones in the summer. Flowers which do not open are called *cleistogamous flowers* (Gr. *kleistos* = closed + *gamos* = *marriage*).

Cross-pollination is believed to add *vigor to the offspring*, but this has not been conclusively proven to be a principle of general application. Many plant breeders, however, accept it as a fact. It is also believed to enable the plant to *vary more readily*, because of biparental inheritance; thus facilitating adaptation, and improvement. The universality of cross pollination should indicate that it is of great importance. In the case of the violet and milk wort, the normal flowers are cross-pollinated; and in this way the vitality and ability to vary are maintained. The cleistogamous flowers provide a greater certainty of the seeds germinating, because they are "planted" in the ground; and the pollen which would be wasted in cross pollination is conserved.

Hybrids.—Pollen which is produced by one kind of plant will not usually fertilize a flower of another species; but if the two species are closely related, or if the two plants are varieties of the same species, the pollen may function. The offspring of such a union will possess characteristics of both parents and is called a *hybrid*. It is well known that if various kinds of squashes, pumpkins, and gourds are grown together; and the seed from the fruit is saved and planted the next year; many varieties of hybrids will be produced, few or none of which, however, will be of any value. Although most hybrids are worthless, many new and valuable varieties of agricultural plants have been produced by intentional or accidental cross pollination between nearly related plants. We will have more to say about this when we study plant breeding.

Laboratory Work.—At least one flower should be drawn and carefully labeled.

Examine various examples of monocotyledonous and dicotyledonous flowers and note the distinctions. Let each student who can, bring one or more specimens to the class.

Try to secure some examples of flowers which are water, wind, and insect pollinated. Compare their stigmas.

31. INFLORESCENCE AND POLLINATION

How are flowers adapted to insure pollination?

The arrangement of flowers on the stem is known as *inflorescence.* Many plants having small flowers bear them in clusters. This makes them more conspicuous, hence easier for insects to find. The methods of grouping the individual flowers to make clusters are various but may be classified under the following heads:—

FIG. 174.—Anthodium of the dandelion in blossom and with seeds.

1. **Anthodium.**—Sunflower, aster, daisy, and dandelion blossoms are a composite of many small flowers borne on a single stem and surrounded by many modified leaves called *bracts* which serve the same function as sepals, but differ from them in that they are usually more numerous and inclose many flowers instead of one. The entire collection of bracts constitute an *involucre.* All of the plants in the COMPOSITÆ family are of this type. Such a flower cluster is called an *anthodium* (Gr. *anthos* = flower) because it resembles a single flower.

2. **Head.**—The flowers of clover, button-bush, teasel, and sycamore are also clusters and are known as *heads*. The anthodium is also often called a head.

3. **The raceme** is well illustrated in the currant, sweet clover, lily of the valley, mignonette, and forget-me-not. In the raceme

FIG. 175.—*Spike* of butter and eggs, *umbel* of geranium, and *heads* of clover.

the flowers grow in their normal position in the axils of the leaves, but the leaves have been reduced to mere scales, and the whole cluster is crowded together. In this type the main plant stem supporting the flower cluster is caleed a *peduncle*, and the small flower stems are called *pedicels*.

4. **The spike and the catkin** are racemes where the pedicels are lacking—the flowers being sessile. The spike is illustrated by the plantin, pickerel weed, and mullen; and the catkin by willow, poplar, birch, and many nut trees. Spikes stand erect. Catkins are flexible.

5. **In the umbel**—illustrated by the cherry, geranium, milkweed, and the ever blooming primrose—the pedicels which are approxi-

FIG. 176.—Compound raceme and compound corymb of two species of goldenrod.

mately equal in length leave the peduncle at one place and are often surrounded by an involucre.

6. **The corymb** is illustrated by the trumpet creeper and hawthorne; and in its compound form by yarrow, iron weed, and boneset. It may be looked upon as a shortened raceme where the lower pedicels are lengthened to bring all the flowers up to a common level. The raceme, the umbel, and the corymb are often com-

pounded to make immense flower clusters. The compound umbels of the carrot family are known to most everyone.

7. **The panicle** is a compound raceme which is well illustrated in oats and other members of the grass family.

ADAPTATIONS.—We have discussed the supposed advantages of cross pollination in the previous study, and will now consider some of the adaptations in the structure of the flower which facilitate it.

FIG. 177.

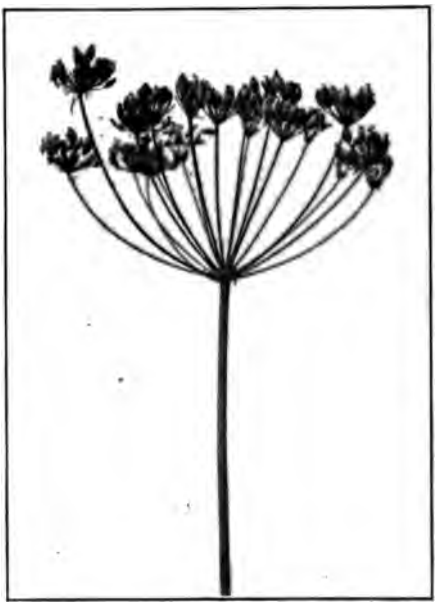


FIG. 178.

FIG. 177.—Catkins of the birch. The staminate catkins are pendant. The pistillate catkins bear seed and are often called cones. They are the small ones which stand erect. (*From Gager.*)

FIG. 178.—Compound umbel of one of the wild members of the carrot family.

1. In the **squash** and its allies the flowers are *unisexual*,—*i.e.*, they do not bear both stamens and pistils, but are of two kinds, commonly termed *true* and *false* blossoms. The true flowers possess a pistil and produce fruit if pollinated, and the false blossoms bear stamens and produce pollen. It is a mistake to think that the false

blossoms are not essential; for if they are removed, no pollen will be provided for the true flowers and no fruit will form.

2. The **willow** bears unisexual flowers as does the squash, but they are not borne on the same plant. A plant which bears one kind does not bear the other. Such plants are commonly called *male*

FIG. 179.—Staminate and pistillate flowers of the squash. Note that the pistillate flower bears a young squash at its base.

and *female*, and they are said to be *diœcious* (of two households). When the two kinds of flowers occur on the same plant, as in squashes they are said to be *monœcious*. Compare the advantages and disadvantages of the two types.

3. **Plantin.**—In many flowers the stamens and pistil do not mature at the same time; the stamens usually preceding the pistil. Since the pollen is all gone when the stigma is ready to receive it, it must

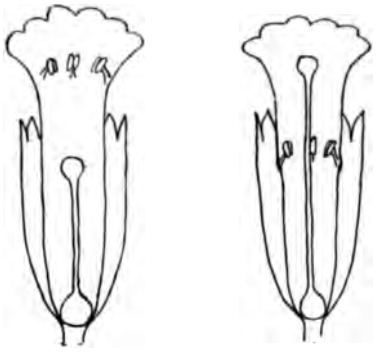


FIG. 180.—Dimorphous flowers of a primrose. Note the positions of the stamens and pistils.

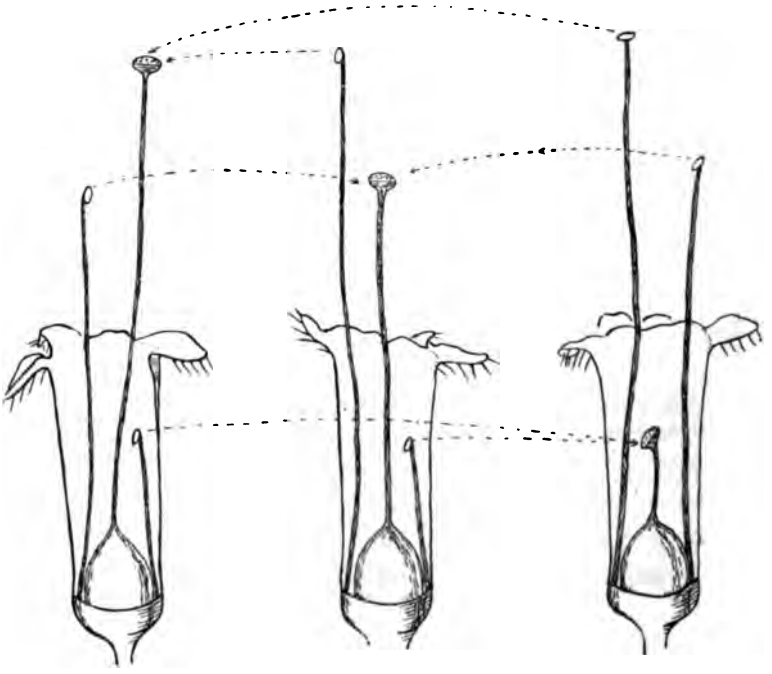


FIG. 181.—Trimorphous flowers of the spiked loosestrife. Note the three lengths of stamens and pistils.

come from some other flower; and cross pollination is assured. The high mallow, plantin, figwort, and clerodendron are good examples of this condition. It is called *dichogamy* (two separate marriages).

4. In some flowers,—such as **primroses,** bluets, the forget-me-not, and the partridge berry the pistils and stamens are of two lengths: some with short stamens and long pistils, and some with long stamens and short pistils. Furthermore, the pollen grains are of two sizes in most species and are sterile on the pistils that occur in the flowers of the kind from which they come; but function on the pistils of the same length as the stamens which produced them. This was worked out by Darwin in a long series of experiments. A bee going and coming among the flowers will be more apt to cross pollinate flowers of this type,—the interchange of pollen being between the stamens and pistils of equal length. Flowers of this type are said to be *dimorphous* (of two forms).

FIG. 182.—Zygomorphic flowers of butter and eggs with a bee forcing its way into a corolla.

Trimorphous flowers occur on the spiked loosestrife (*Lythrum salicaria*) and the pickrel weed. In these flowers the stamens and pistils are of three different lengths. Each flower contains two sets of stamens, and only one kind of flower is found on a single plant. There are, then, three kinds of plants in each species, and three kinds of pollen are produced.

5. Flowers,—such as **roses,** morning-glories, and poppies are radially symmetrical, and are said to have *actinomorphic* (Gr. *actinos* = ray + *morphos* = form) or *regular* corollas. They are usually open to all comers among the insects; thus, much pollen is wasted by insects which visit many kinds of flowers. Flowers of this type show no special adaptions to facilitate cross pollination. On the other hand, many flowers are especially modified in shape, making it diffi-

cult or impossible for certain insects to visit them. They are often especially adapted to a limited number of visitors. Examples of *irregular* or *zygomorphic* flowers are the violet, snapdragon, sage, and the mints. The snapdragon (*Atirrhium*), turtle-head (*Chelone glabra*), and butter and eggs (*Linaria vulgaria*) have closed corollas which are forced open by bees; and other insects are, to a large extent, prevented from entering.

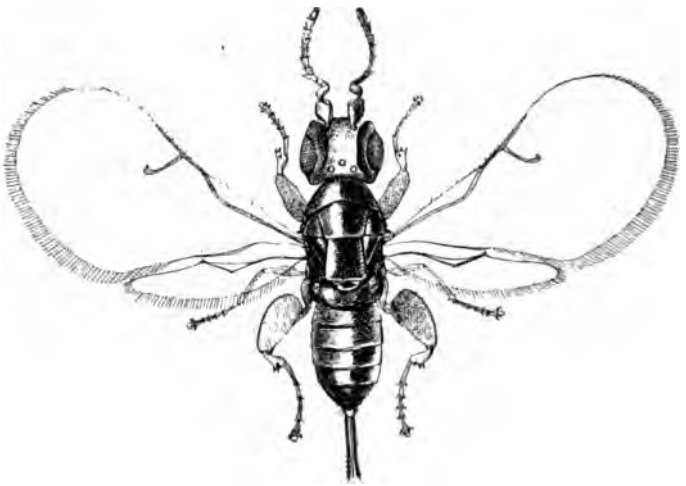


FIG. 183.—Blastophaga, the insect which pollinates figs. (*U. S. Dept. of Agriculture.*)

The fruit of the fig will develop whether the blossom is pollinated or not, but seeds will not form, and the fruit is of an inferior grade. In its native country the fig is pollinated by the fig insect (*Blastophaga grossorum*). It is the only insect known which can enter the fig flower and pollinate it. Fig growers in California could not raise perfect figs until this insect was imported. This is one of the most remarkable adaptions between insects and flowers that is known.

Museum Projects.—Examples of the various types of inflorescence may be mounted by individuals and preserved in the museum cases. These preparations

should be carefully labeled and should bear the names of those who have helped to make them.

Laboratory Suggestions.—Study as many types of structure which facilitate cross pollination as possible.

32. CELL DIVISION AND FERTILIZATION

How do cells multiply? What are chromosomes, and what work do they do? Why must eggs be fertilized?

A cell is a unit portion of protoplasm containing a nucleus, and is the simplest structure known, possessing the characteristics of living matter. The cells of plants and animals are very much alike. The chief difference being that the plant cell usually contains chlorophyll and possesses a cell wall made of cellulose, while animal cells contain no chlorophyll and have a cell wall of a protein material;

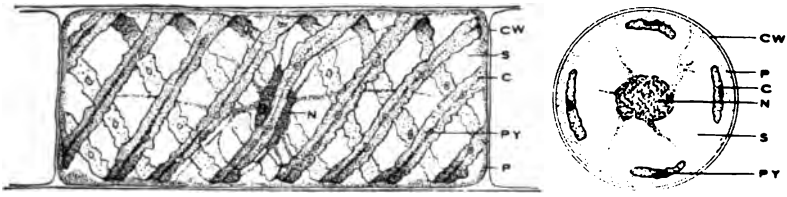


FIG. 184.—A cell of spirogyra seen in cross section and side view. *C*, chloroplasts; *CW*, cell wall; *N*, nucleus; *P*, protoplasm; *PY*, pyrenoid; *S*, cell sap.

but these differences are not constant. The gametes of many algæ, for instance, have no cellulose wall; and the entire group of fungi are devoid of chlorophyll.

A drawing of a cell of spirogyra appears in Fig. 184. Note that it is bounded by a *cell wall*, contains *cell sap* and *protoplasm*, is traversed from end to end by spiral ribbons of chlorophyll (*chloroplasts*) which contain denser areas called *pyrenoids*, and contains a central *nucleus* with processes running throughout the cell.

The nucleus is the most important part of the cell; without it the cell can not remain active and ultimately dies. It is usually centrally located, and unless obscured by coloring matter, is observable under the microscope. It can be made more distinct by staining with iodine. A nucleus is normally bounded by a *nuclear wall*, on the outer edge of which a body, called the *centrosome*, appears

during cell division. The protoplasm within the nucleus is traversed by a network of fibers called *linin*. A small, round body, called the *nucleolus*, is usually present. Its significance is unknown.

The most important structures within the nucleus are the chromosomes (Gr. *chroma* = color + *soma* = body), so called because they are easily stained in microscopic preparations. They are of various shapes and sizes, and at some stages in the life history of the cell seem to disappear, but their identity is never lost. They are always found in constant number and form, in any given species of plant or animal.

Cells Multiply by Division.—In one type called *spore formation* which occurs in the algæ, and protozoans, many small spore cells are formed within the parent cell. When they are ripe the old cell wall breaks open; they escape, grow, and become cells like the parent.

In another type, called *fission*, the cell divides into two equal halves by an infolding of the cell wall and a division of the material within it. This phenomenon appears very simple but may be very complex. Is is the common method of growth or reproduction among the bacteria and blue-green algæ.

In the higher plants and animals cell division takes place by a process known as karyokinesis (Gr. *karyon* = *nucleus* + *kinesis* = movement). It is also called *mitosis* (Gr. *mitos* = thread). The process is similar for both plants and animals. We will describe a general type which should be modified to fit special cases.

1. In the figure, A shows the resting cell with its nucleus containing chromatin and linin (CH), and the centrosome (CE). It may be noted here that plant cells do not have a centrosome. The centrosome divides and the halves migrate around the nucleus, or move apart and the nucleus is drawn up between them. Around each of the halves of the centrosome, rays appear, which cause them to look like stars (B). Hence they are called *asters* (Gr. *aster* = star). *The chromatin is organized into a definite number of bodies*—four in this case—which are the chromosomes. They migrate to the central plane of the nucleus and arrange themselves there in the form of a circle (C), and are suspended by ray-like processes from the asters. The entire figure resembles a *spindle* and is so called. The

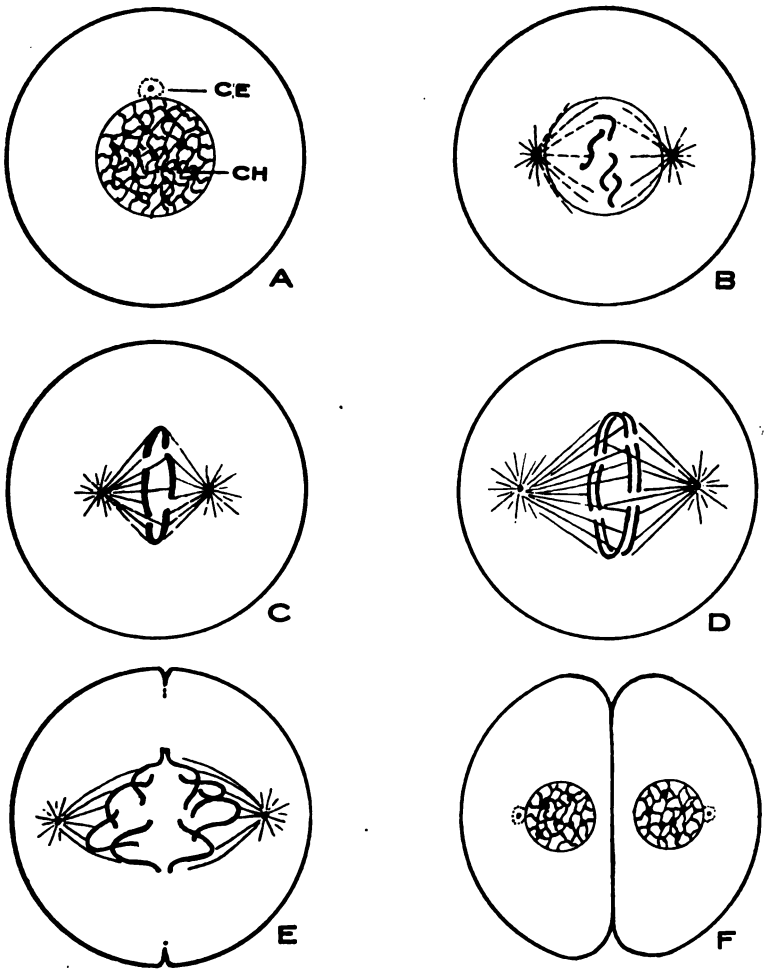


FIG. 185.—A diagram of cell division. The stages of the process are described in the text.

spindle occurs in both plant and animal cells. It is often compounded in plants. These changes constitute the first or *prophase* of the process.

2. In the second stage, *each chromosome splits longitudinally into two equal halves* which soon move apart (D). It is important to note that the splitting is lengthwise, for this leaves each half identical in structure with its counterpart. When transverse splitting occurs in reproduction, the halves may not be identical in structure. The second stage is called the *metaphase.*

3. In the third stage *the chromosomes move toward the asters;* probably under the influence of the rays of the spindle, and finally group themselves near the poles of the spindle (E). This phase is called the *anaphase.*

4. In the last phase which is the *telophase, the process is completed* and two new nuclei are formed. They are similar to the one from which they were derived except that they may be smaller in size (F). By the time the process is complete the cell wall has usually constricted the cell into two equal halves, but in some cases the cytoplasm does not divide equally.

While the number of chromosomes in the cells of the plants of a given species is constant, *there are always twice as many in the cells of the sporophyte generation as there are in the gametophyte generation.* The asexual spores, produced by the sporophyte in all of the bryophytes, pteridophytes, and spermatophytes, and in some red algæ are formed in groups of four. These spores are, therefore, called *tetraspores.* The four spores are formed from a single cell by two divisions, during which the chromosomes are reduced in number by one-half. This leaves one-half as many chromosomes in each of the four spores as were in the parent cell from which they came. The megaspores of the higher plants are, in general, developed singly; however, the other three cells are formed but remain undeveloped; the megaspore being the only one of the four to complete its development. Pollen grains are always produced in groups of four also; but in this case, all four spores become mature.

Since the gametophytes are produced from asexual spores (tetraspores) they have the reduced number of chromosomes. It is convenient to let x stand for the reduced number and 2x for the

double number. All gametes—whether they are eggs and sperms or not—possess the x number of chromosomes. When the gametes fuse in conjugation or fertilization, the chromosomes do not fuse with each other, but remain distinct; hence the double number (2x) is restored in the sporophyte which grows from the zygospore or fertilized egg. In the simpler algæ, which have no sporophyte generation and produce no tetraspores, the 2x number, of course,

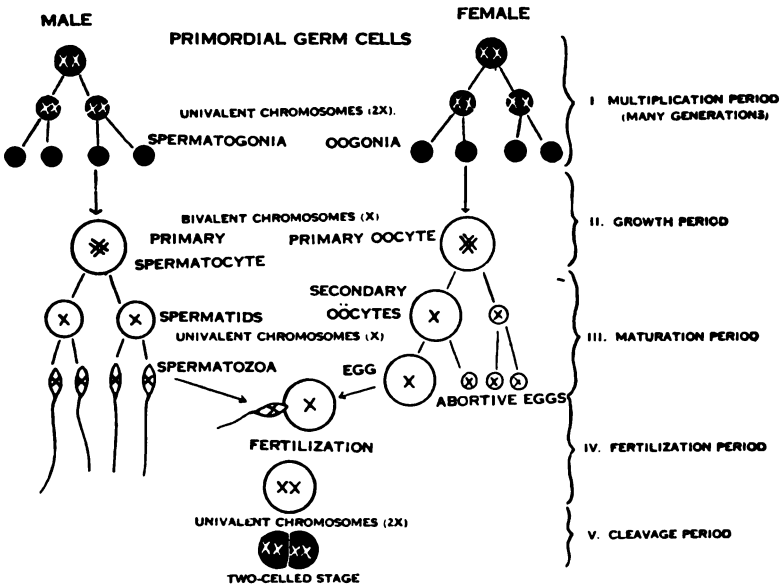


FIG. 186.—A diagram illustrating the method of developing sperms and eggs in animals. Note that the 2x number of chromosomes which is the normal number is restored in fertilization giving the new generation the same number as the parent generation. (*From Galloway.*)

does not occur. Since the lower algæ have the x number, are gametophytes, and came into existence first, we may look upon the reduced number (x) as the normal number in spite of the fact that it occurs in the suppressed phases of the life history of the seed plants.

In animals, sperms and eggs are produced in special organs known as *spermaries* and *ovaries* respectively. Certain cells in these struc-

tures are known as *germ cells*. They contain the same number of chromosomes as the other cells in the animal's body and multiply by karyokinesis as do the other cells. When eggs are to be produced the germ cells of the ovary become greatly enlarged. The enlargement is due to the fact that food matter (yolk) is being deposited within them. When they have attained their full size, a process known as *maturation* occurs. It varies in different forms, but the following may be taken as a typical case. (See Fig. 186.)

As is shown in the diagram the reproductive bodies contain cells which are known as *primordial germ cells*. By a series of divisions they produce *oögonia* or *spermatogonia* according to whether the animal in question is a female or a male. These cells produce *primary oöcytes* and *primary spermatocytes*, which are relatively large cells. Each of these cells, by a series of two divisions produces *eggs* or *spermatids*, each cell producing four. In the case of the sperms, the cells go through a reorganizing process during which they become sperms or *spermatozoa*. In the case of the eggs, only one functional egg results from the process. The other three of the four are abortive, and can not be fertilized. It will be noted from the diagram that when the secondary oöcytes and secondary spermatocytes are formed the chromosomes do not divide. This leaves only one-half the number in each cell. Therefore, this is known as the *reducing division*.

Maturation provides for the reduction of the chromosomes to one-half the *somatic* (body) number; and in the egg, provides for the storage of food on which the embryo may live for a time. It may be noted here that all animal eggs do not possess a large quantity of yolk.

Eggs which are retained within the body of the parent are fertilized within the body, but those which are shed into water are usually fertilized after they leave the body. In either case the sperm usually swims to the egg, penetrates the egg membrane; and the nucleus of the sperm—with its centrosome and chromosomes—moves to meet the egg nucleus. When they meet, they fuse,—the chromosomes remaining distinct; and by this fusion the egg is fertilized and ready to develop into an individual like the parent. It is evident that fertilization restores the 2x number of chromosomes.

Reproduction in plants and animals differs in that in animals no asexual spores are produced and the reduction of the number of chromosomes takes place in the production of eggs and sperms, instead of in the production of asexual spores. In each case the number is restored during fertilization.

It should be remembered that the only material which is received by the fertilized egg in equal quantities from both parents is the chromosome material. Since characteristics are inherited equally from both parents, the chromosome is believed to carry the *determiners* of heredity.

Laboratory Suggestions.—If the students are skillful in the use of the microscope, mitosis may be shown with prepared longitudinal sections of the onion root tip, or with the eggs of the sand worm, *Neres*, which may be had from dealers.

Note.—The teacher will find it of value to the students to have diagrams of cell division, conjugation, and etc. made on the blackboard with colored chalk to be referred to in recitation.

33. THE LIFE HISTORY OF FLOWERING PLANTS

How are the seeds of flowering plants formed?

The flowering plants are called ANGIOSPERMS (meaning covered seeds) because their seeds are inclosed in an ovary. The pines and their allies are called GYMNOSPERMS (meaning uncovered seeds) because they bear their seeds on the surface of the scales of cones. There is really very little difference in the life history of the two groups. The stamens and carpels are modified cone scales which, it will be recalled, are modified leaves; and are called *sporophylls*. The anthers of the stamens are *microsporangia*, and the pollen grains are *microspores*. Growing out from the inner walls of the carpels are structures called *ovules*. They are the *megasporangia*, and each bears a *megaspore*. As shown in the illustration, an ovule consists of an *outer* and *inner integument* which together form the seed coats of the mature seed. They grow around a central part called the *nucellus*, but do not completely enclose it. A round opening is left on one side, usually near the place of attachment. It is called the *micropyle* (little gate) and usually receives the end of the pollen tube in fertilization. The megaspore is formed in the tissue of the nucellus.

As in the pine, the microspore and megaspore develop into the male and female gametophytes respectively. We will discuss the development of the male gametophyte first.

Pollen grains are of various shapes and sizes. When one falls on the stigma it absorbs moisture by osmosis and begins to swell. A tube grows forth from it and penetrates the tissue of the stigma and style by dissolving it. Before the pollen grain is shed from the anther it has begun its development and two nuclei are formed. One of them occupies a position in the end of the pollen tube and is called the *tube nucleus*. The other follows closely and is called the *generative nucleus*. It soon divides to form two *sperm nuclei* which

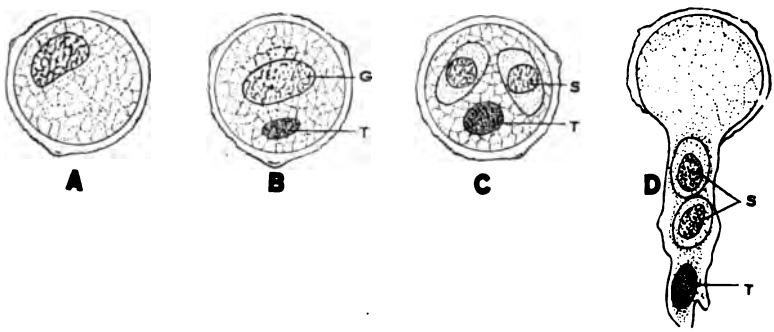


FIG. 187.—Development of the pollen grain (male gametophyte). *A*, the pollen grain with one nucleus; *B*, the first step in the development of the gametophyte. The nucleus has divided to form a generative nucleus (*G*) and a tube nucleus (*T*); *C*, the generative nucleus has divided to form two sperm nuclei (*S*); *D*, the pollen grain has germinated and put forth a tube, and the nuclei have passed down into it.

function in fertilization. The pollen grain may be looked upon as a male gametophyte at any time after it has begun to develop (even before it is shed from the anther), and the pollen tube corresponds to an antheridium which produces only two sperms.

The pollen tube traverses the entire length of the style in a very short time, and enters a locule of the ovary. It usually grows along the carpel wall and enters an ovule through the micropyle. It finally reaches the female gametophyte by dissolving its way through the nucellus. Pollen tubes are always microscopic in size, and very

little was known about fertilization in flowering plants until microscopic technique had become highly developed.

During the growth of the pollen tube within the nucellus, the megaspore develops into a female gametophyte; but it is very degenerate. When mature it contains only eight nuclei,—developed as follows: The megaspore draws nourishment from the tissue of the nucellus, enlarges, and its nucleus divides (see diagram). Each nucleus migrates to an opposite end of the megaspore tissue which is now known as an *embryo sac.* (It received this name because the embryo ultimately developes within it, and because at the time it was named, its nature was not understood.) Each nucleus then divides twice forming eight cells,—four in each end. Three of the four in the end which is usually opposite the micropyle of the ovule are called *antipodal nuclei*, and soon degenerate. The other migrates to the middle of the embryo sac and here meets one of the four from the other end, and fuses with it. Of the three left in the end near the micropyle two are called *synergids* (helper cells) and are thought by some investigators to guide the sperms from the pollen tube when they enter the embryo sac. They may be degenerate egg cells or the remains of a degenerate archegonium. The other of the four nuclei in this end is an *egg nucleus*, and fuses with one of the sperms from the pollen tube. This fertilized egg develops into the embryo of the seed.

The second sperm of the pollen tube passes to the middle of the embryo sac and fuses with the pair of nuclei there, which have come from opposite ends of the embryo sac. This constitutes a triple fusion of nuclei and is known as *double fertilization.* It is unknown outside of the angiosperms, and probably originated among them as a result of the natural tendency of the cells to conjugate. This nucleus with a triple origin develops by a continued cell division into a cellular tissue in the young seed which is called the *endosperm*, hence it is called the *endosperm nucleus.* It will be noted from the above that the endosperm of the seed of the flowering plant, unlike that of the seed of the pine, is a secondary, cellular growth within the embryo sac. It is, therefore, a different structure; but bears the same name. Furthermore it has a biparental ancestry inheriting from both the embryo sac and the pollen tube. This

FIG. 188.—Development of the embryo sac (female gametophyte). *A*, a section through a pistil showing a single ovule (megasporophyll) in the locule of the ovary. The megaspore is the largest of four cells in the center of the ovule. Note that it is surrounded by three coats,—the inner and outer integuments (*I*) and the nucellus (*N*) all of which are better shown in *C*. Note how the pollen tube reaches and enters the micropyle of the ovule. *B* shows the development of the eight nuclei in the embryo sac. *C* shows the mature female gametophyte and the tip of the male gametophyte; the former containing eight nuclei and the latter containing only three. *AP*, antipodal nuclei; *E*, egg nucleus; *EN*, two nuclei fusing to form the endosperm nucleus; *I*, integuments; *N*, nucellus; *S*, sperm nuclei.

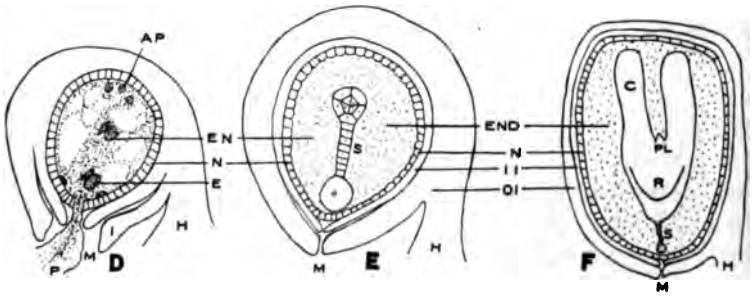


FIG. 189.—Development of the embryo. This figure is a continuation of the preceding. *D* shows the antipodal cells (*AP*) disappearing, and the fusion of the two sperms with the endosperm nucleus (*EN*) and the egg nucleus (*E*). The remains of the pollen tube (*P*) are seen in the micropyle (*M*). *E* shows the developing embryo with its suspensor (*S*) and the endosperm (*END*). *F* shows the young embryo and its parts. *C*, cotyledons; *PL*, plumule; *R*, root. Note that the embryo is surrounded by four coats. *END*, endosperm; *N*, nucellus; *II* and *OI*, inner and outer integuments. *H* is the hilum.

FIG. 190.—An ear of sweet corn showing xenia. The smooth kernels have been fertilized with pollen of a yellow dent race. (*U. S. Dept. of Agriculture.*)

accounts for the fact that red or blue kernels sometimes appear on white ears of corn. Part of the pollen which has fertilized the ear has come from red or blue corn, and the color appears in the endosperm of the seed. This phenomena is called *xenia* (from Gr. = foreign), and was described in 1900 by Webber in Bulletin 22, U. S. Department of Agriculture. It is obvious that the endosperm can not inherit from the pollen parent unless double fertilization occurs. Xenia does not occur in seeds which have no endosperm when ripe.

The developing embryo lies in the endosperm and draws its nourishment from it. In some seeds, —as the bean, pea, and squash, the endosperm is practically all absorbed by the time the seed is ripe. In others,—as the grains, caster oil plant, and poppy, the endosperm is found in considerable quantity in the mature seed, and is absorbed during the early life of the seedling after the seed germinates.

As in the gymnosperms, the embryo finally comes to lie in the middle of the endosperm by producing a preliminary growth called the *suspensor*. A group of cells is formed about the end of this structure, and out of this group the

parts of the embryo make their appearance. It should be kept clearly in mind that the embryo is the young sporophyte, and, in miniature, possesses a root, a stem, and leaves. It is a resting stage in the life history of the plant, and serves to preserve the life of the plant during an unfavorable period (as winter) as well as to reproduce the plant.

It should be interesting at this point to recall that the thrifty, green gametophytes of the moss are still represented in the flowering plants by the degenerate pollen grain and its tube, and the embryo sac. The well developed antheridia and archegonia of the moss have ceased to be cellular in structure or to be recognizable as organs. On the other hand, the moss sporophyte which was parasitic upon the gametophyte has become, in the seed plants, the stately pine, giant oak, and beautiful lily. No miracle was ever more marvelous than the evolution of plants!

Suggestions.—This is a difficult study. The author has found it helpful to review the life histories of the moss, fern, and pine in a combination of a quiz and chalk-talk, illustrating the various structures as the lesson progresses. The life history of flowering plants may then be outlined in the same way. The microscopic features may be illustrated from prepared slides which can be purchased from the supply-houses.

34. THE USES OF FRUITS

What part do fruits play in the life history of plants?

To the botanist *a fruit is the growth which results from the fertilization of a flower.* It may be simply the ripened ovary, called the *pericarp* (Gr. *peri* = about + *karpos* = fruit), and the seeds within it. In many of the edible fruits the calyx and receptacle are included in the growth and form a part of the fruit. To the gardener tomatoes and squashes are vegetables; to the botanist they are fruits.

Fruits may be classified as *dehiscent* and *indehiscent* according to whether they dehisce (open) or not. The dehiscent fruits may be discussed under four heads: namely,—*legumes*, *follicles*, *siliques*, and *capsules*.

The legume is a pod, well illustrated in the pea and bean; and consists of a single, long carpel (morphologically a leaf) folded along its midrib so as to inclose a single locule. The seeds are alternately

attached to each side of the carpel along the midrib. It splits open along both edges when ripe, and in some forms each half curls in such a way that the seeds are thrown to some distance.

The follicle is a pod which differs from the legume in that it opens along only one edge. It is well illustrated in the monkshood and columbine.

The silique resembles the legume but contains a partition.

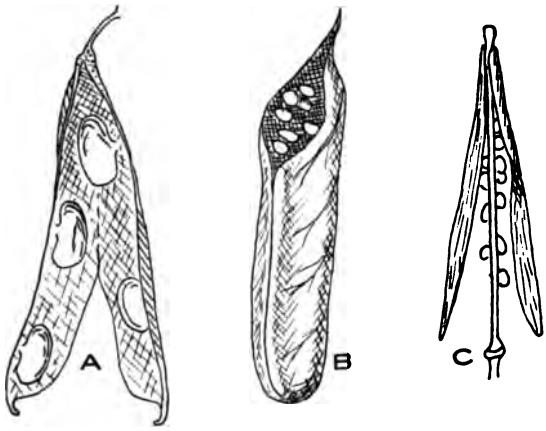


FIG. 191.—Three dehiscent fruits. *A*, the pod of a bean; *B*, the follicle of the monk's-hood; *C*, a silique of a mustard.

The capsule is a compound ovary consisting of two or more carpels and opens in various ways. It is illustrated in the morning-glory, poppy, and jimson-weed. Many capsules retain their seeds for a considerable time, and when they are shaken by the wind or passing animals, the seeds are shaken out. Practically all dehiscent fruits are dry when ripe.

The indehiscent fruits may be divided into two groups: namely, those which are *dry* when ripe and those which are *fleshy*. The *dry indehiscent* fruits may be discussed under five heads as follows: *akenes*, *grains*, *nuts*, *samaras*, and *loments*.

The akene is illustrated in the buttercup, wood anemone, sunflower, and dandelion. It consists of an entire pistil, does not open, and contains only one seed. In the COMPOSITÆ family (dande-

FIG. 192.—Photograph of the capsules of the evening primrose on the left and butter and eggs on the right.

FIG. 193.—Photograph of four types of indehiscent fruits. The akene is illustrated by a sunflower seed, grains by corn, nuts by an acorn, and the samara by the winged fruit of the soft maple.

lion and thistle) the fruit develops from an inferior ovary and the calyx may persist as a pappus which acts like a parachute when the fruits are distributed by the wind.

The grains are illustrated in all of the grains and grasses. They resemble akenes, but the seed coats are firmly fused with the wall

FIG. 194.—A loment or sticktight of one of the legumes. Note that it has been developed from a legume pod.

of the ovary which is comparatively thin. In the akene a space exists between the seed coats and the ovary wall (pericarp). Akenes and grains are usually called seeds. They really are more than seeds; they are entire, one seeded fruits. Popular usage, however, permits the use of the word *seed* in referring to them, but the student should understand that they are fruits.

The nuts are also very much like akenes, but are larger. They

are usually partly or entirely enclosed in an involucre from which they separate when ripe. The prickley hulls of chestnuts and beechnuts, the cups of acorns, and the leafy hulls of the hazelnuts are involucres. The Brazil nut and almond are not nuts. The

FIG. 195.—A cluster of ripe cockleburs in the fall of the year.

former is a seed, and the latter is the inner wall of a stone fruit or drupe. How are nuts distributed in nature?

The samaras are winged fruits, and are illustrated in the elm, ash, alianthus, and various maples. The seed of the pine is also winged and resembles the fruit of the maple, but it is not a fruit;

it is a seed. The entire pine cone is a fruit. Many of the winged fruits spin as they fall. Let some maple fruits or some pine seeds fall, and watch them spin. Winged fruits and seeds are distributed by the wind.

The loment is the fruit of the sticktights. It is a legume which is divided into sections. It does not open, but each section containing one seed is separated when ripe. They are covered with small hooks which fasten into the hair of passing animals, thus providing

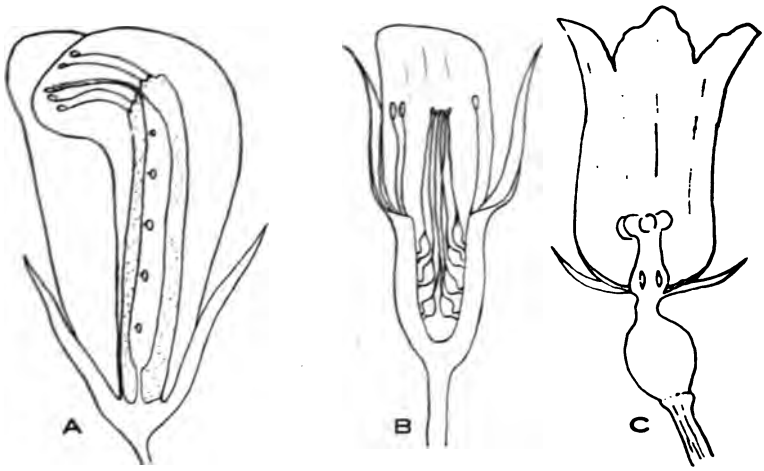


FIG. 196.—Three types of fruit buds. *A*, a bud of the sweet pea with a superior ovary; *B*, bud of a rose with an intermediate type of ovary. The ovules are sunk into the receptacle. *C*, bud of squash with an inferior ovary.

for the distribution of the fruit. Various fruits, of many kinds, are provided with hooks, and are distributed as are the sticktights. They are commonly known as *burs*, and occur in the hound's-tongue, burdock, sand-bur, and cocklebur.

The structure of fleshy fruits depends largely upon the arrangement of the parts of the flower from which they come. In such flowers as the apple, squash, pumpkin, rose, and gooseberry the ovary is sunk deep into the receptacle, and the calyx is brought up above the ovary in such a manner that the sepals and petals are attached to its upper part. Such flowers are said to be *superior*,

and the ovary is *inferior*. In flowers like those of the peach, cherry, blackberry, and bean the calyx is attached to the base of the pistil. These flowers are *inferior*, and the ovary is *superior*. Fruits developed from inferior ovaries contain part of the receptacle and calyx. Those developed from superior ovaries do not contain any part of the calyx but may contain a part of the receptacle.

The flesh of fleshy fruits is eaten by birds and animals. The seeds are often bitter, and are usually not eaten. If they are they usually pass through the body undigested. The seeds of many berries are scattered over wide areas in this way by birds. In your walks through the country note the large number of plants bearing fleshy fruits that are found along fence rows. How did they get there?

THE SIMPLE FLESHY FRUITS may be discussed under five heads as follows: *berry*, *pepo*, *hesperidium*, *pome*, and *drupe*.

Berries, botanically speaking, are of two kinds: those that contain part of the calyx; as the gooseberry, currant, huckleberry, and banana; and those that do not contain any part of the calyx; as the tomato, grape, and persimmon. The berry is rather thin skinned, and contains several or many seeds. It is usually a fleshy, compound or many loculed ovary.

The pepo occurs in the family CUCURBITACEÆ and includes the following: cucumbers, melons, gourds, squashes, and pumpkins. It results from the development of an inferior ovary; and may be solid as in the watermelon, or hollow as in the muskmelon.

The hesperidium is a thick-walled, many-carpelled ovary. Oranges and lemons are examples. Both the pepo and hesperidium are special modifications of the berry.

The pome is illustrated in the apple, hawthorne, pear, and quince. It results from the development of an inferior ovary with several—usually five—locules inclosed by heavy carpels, constituting a core The greater part of the fruit develops from the calyx and receptacle. The fruit of the rose is called a *hip* and is similar to the pome, but the hard core does not occur. The pome and hip occur in the family ROSACEÆ.

The drupe is often called a stone fruit. The peach, plum, almond, cherry, and black haw are drupes. It is a ripened ovary containing

no part of the calyx as does the pome. It normally contains one seed surrounded by the inner wall of the pericarp (carpels) which is hard, and an outer pulpy wall. When the flesh is eaten the hard stone is usually rejected, and if dropped in a favorable locality may reproduce the plant.

THE COMPLEX FLESHY FRUITS may be grouped under three heads: namely *aggregate fruits*, *accessory fruits*, and *multiple fruits*.

FIG. 197.—A complex fleshy fruit. Each raspberry fruit develops from one blossom. It is an aggregation of fleshy carpels. (*U. S. Dept. of Agriculture.*)

In the **aggregate fruits** of the blackberry and raspberry, each seed is surrounded by a pericarp exactly like a drupe, and these little *druplets* are united to a common receptacle. In the blackberry the receptacle is a part of the fruit. In the raspberry it is not.

In the **accessory fruit** of the strawberry, the receptacle forms the fruit. The seeds are dry akenes on its surface.

In the **multiple fruits** of the mulberry and pineapple, many flowers are fused into one fruit-mass. The pineapple has lost its seeds due to selective breeding and cultivation. The cone of the pine may be

considered a multiple dry fruit. Why are fleshy fruits usually hard seeded, bitter or sour before ripe, and highly colored when mature?

Classification of Fruits

Dehiscent	**Indehiscent**		
legumes	*Dry*	*Fleshy*	
follicles	akenes	*simple*	*complex*
siliques	grains	berry	aggregate
capsules	nuts	pope	accessory
	samaras	hesperidium	multiple
	loments	pome (hip)	
	(burs)	drupe	

Museum Project.—Make collections of various types of fruits. Study them, mount them properly, and preserve them for the museum.

Laboratory Study.—Draw specimens of types of fruits in outline and section.

35. SEED DISTRIBUTION

How are seeds distributed, and why?

"A moment's reflection will convince the student that the dispersion of the seed to some distance from the parent plant is of vital importance to the continuance and well-being of the species. If the seeds were to fall immediately beneath the plant, a crowd of offspring would result, growing so close together as to deprive each other of a sufficient amount of sunlight and raw materials from the soil. Or, if the parent were a perennial, it would overshadow and starve the seedlings. Even with some means of seed dispersion there is apt to be greater competition between individuals of the same species than between those of different species, because plants of the same species require the same proportions of the different soil constituents, and having the same habit of growth, crowd each other more than the same number of indivuduals of different species distributed over the same area would be apt to do. One need only compare the number of seedlings of a particular species appearing above the soil in a given area with the number of those which actually reach maturity in the same area to be convinced of the struggle which is taking place among them, with fatal results except to the relatively few individuals which are stronger and more rapid growers than

their fellows. Any devices which aid in dispersing the seed help to ameliorate these conditions." (Stevens, *Introduction to Botany*.)

Many devices are found in fruits and seeds which provide for dispersion, and various plants have become adapted to nearly every available agency.

I. **Elastic Mechanisms** have been developed in many plants to accomplish this end. The cranesbill throws its seeds some dis-

FIG. 198.—The squirting cucumber (*Ecbalium*) discharging its seeds as it breaks from its fruit stem. (*From Jenkin's Interesting Neighbors*.)

tance by the valves (carpels) of the fruit springing up when dry, and throwing out the loosely held seeds. Nearly everyone knows the touch-me-not for its pecular method of ejecting seeds from the capsule when touched.

Morning-glories, evening primroses, the mullen, and the jimson weed hold their seed in capsules, and so do not shed them all at one time. Animals in passing may bend them down, and on springing up the seeds are thrown out. Some seed cases of this type may hold their seeds all winter.

The stroller in the woods in early autumn is familiar with the

bombardment of the witch hazel seeds from their opening seed cases. The fruit of the sand-box tree of tropical America explodes

FIG. 199.—Milkweed pods and their tufted seeds. Note how the pod opens to let the seeds out.

when dry with a report like that of a pistol. The fruit of the squirting cucumber is very much distended when ripe. When it falls from the plant, the end of the stem pulls out of the tissue of the

fruit leaving a hole through which the contents of the fruit, including the seeds, squirt with considerable force. Other plants with elastic mechanisms for seed dispersal which may be investigated by the class are the pansy, violet, Jersey tea, wild balsam, and herb Robert.

II. **Wind Distribution.**—Perhaps the most remarkable and successful dispersion adaptions are those that occur in connection with wind distribution. The samaras of the ash, elm, and maple have been mentioned in the discussion of fruits. The seeds of the catalpa, pine, and trumpet creeper are winged, and are carried by the wind much as are the above mentioned fruits. Winged seeds may be carried many rods before a strong wind.

The akenes of the thistle, dandelion, and lettuce were also mentioned in the study on fruits. The seeds of cotton-wood and the milkweeds are supplied with hairs, and are carried by the wind as are the tufted akene fruits. Such structures are often carried up to great heights, and may be carried many miles before a strong wind.

Some structures are rolled over the ground by the wind, and scatter their seeds as they go. Tickle grass (*Panicum capillare*) and squirrel-tail grass (*Hordeum jubatum*) break off below the flower clusters and roll before the wind. The grains loosen, and come off as they go. The awns of squirrel-tail grass may cling to passers by, and be dispersed in this way also. The common tumbleweed (*Salsola*), peppergrass (*Lapidium*), and others break off at the ground and roll about over the fields until snow falls. The Russian thistle tumbleweed may even cross fences by being piled up along the fence until the level of the top is reached, then those coming afterward roll up the incline over their comrads, and the fence is passed! A large plant may carry 200,000 seeds, and scatter them over a great area.

III. **Water Distribution.**—The seeds of many water plants float on the water, and under the influence of the wind or currents may be carried to a new location. Plants of many kinds are apt to spring up on the shore line of a pond or on a newly formed island. The fruits of the cocoanut are believed to have been carried to many uninhabited islands by floating on the ocean. The top-shaped fruits of a yellow water lily bend over and drop some of their

nut-like seeds to the bottom of the water when they are ripe. Others are retained in the capsule which floats away, thus the species is maintained in its position upstream, and the current or wind may carry the capsule to a new locality. (See Fig. 200.)

IV. Distribution by Animals.—Birds are more important than any other animals except man as distributers of seeds. The seeds of many small, fleshy fruits pass through the intestine of birds

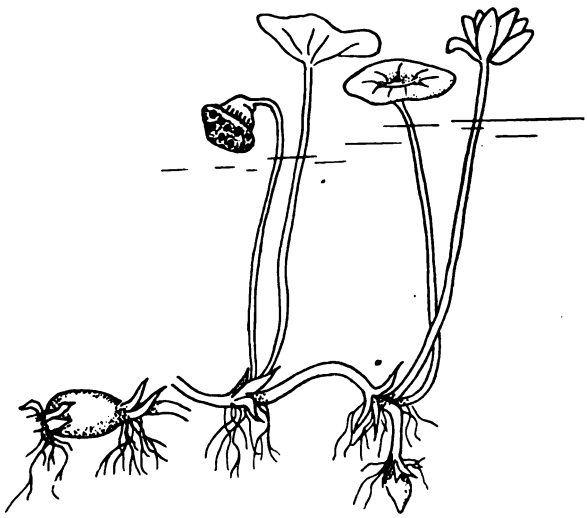


FIG. 200.—A yellow water lily, *Nelumbo lutea*, showing its peculiar seed capsule. It may also propagate itself by tubers. Two of these are shown in the illustration.

undigested; since birds fly great distances the seeds are rapidly and efficiently distributed. The seeds of hawthorne, juniper, raspberry, blackberry, strawberry, wild grape, sumach, elder, and gooseberry are known to be distributed in this way. This accounts for the relative abundance of these plants along telephone lines, fences, and under dead trees. Fruits which have pits or seeds too large to be swallowed may be carried some distance from the parent plant and eaten, and the seeds dropped on the ground. The author once counted 109 cherry stones within a space of one square

yard along a fence which was about one hundred yards from a group of wild cherry trees.

Small seeds are often mixed with the mud on the feet of birds and other animals. Darwin germinated eighty two seeds from the mud taken from the feet of a partridge. Seeds are not only

FIG. 201.—A cluster of elderberries. They are distributed by birds. On your field trips note how often you see elderberries growing along fence rows and other places where birds are apt to alight.

carried in considerable quantity in this way, but are effectively planted in the footprints of the animal carrying them.

Many fruits and seeds are provided with hooks or barbs which catch in the fur of animals or the clothing of people. The cocklebur and burdock fruits often remain in the mains and tails of horses, the tails of cattle, and the wool of sheep for a very long time. More than ten species of the burr marigold (*Bidens*) are famous for their

clinging qualities, and are known as beggar-ticks, stick-tights, Spanish needles, and tick seeds. The loments of the LEGUMINOSÆ family were mentioned in the previous study. The stick seeds and hooked nutlets of the various species of the borage family are also well known. (See Figs. 194 and 195.)

The distribution of nuts is somewhat difficult to understand. They are large seeded, hence much energy goes into their making. They

FIG. 202.—The hooked fruits of the burr marigold, *Bidens*. They remain on the plant all winter unless they are carried away by some passer by.

are all eaten by animals and some by birds. Nearly every nut has various beetle larvæ which prey upon it. Woodpeckers store nuts and acorns, and eat the grubs out later. Blue jays and squirrels store away and eat great quantities of nuts. It must be evident that with this host of enemies a nut has small chance of surviving, but the trees live many years, and if each tree during its lifetime establishes another to take its place when it dies, the race will persist. Some of the nuts which are hidden away are not found again by the animal which hid them, and some of them are in situations favorable for growth. Some of them are dropped for various reasons while being carried. Squirrels have a mania for burying nuts in the ground in the fall of the year. This serves to plant them.

Laboratory Work.—Let various seeds fall from a point near the ceiling and note which fall the fastest. If a wind is blowing which will be carried the farthest? Note how beautifully the seeds of the maples and pines spin. Draw some of them.

Field Collections.—Collect as many seeds as possible and classify them according to their methods of distribution. Save them.

36. THE PROPAGATION OF PLANTS

How are plants propagated in nature and by man?

The fundamental purpose of plant propagation is the multiplication of the number of individuals, but since many domestic plants tend to revert to an ancestral condition when raised from seed, the increase must be secured without permitting the quality of the stock to deteriorate. Many domestic plants are seedless or do not breed true from seed. These must be propagated by some other means. The true plant propagator should also be a plant breeder,—*i.e.*, he should improve the quality of the plants which he grows from year to year; but we will have more to say about this in another study.

Propagation by Spores and Seeds.—We have seen how the algæ, liverworts and mosses, and ferns propagate themselves by spores. These spores may be sexual or asexual, and are produced in great numbers. They have the disadvantage, however, that they contain no reserve food matter, and must secure food immediately after germinating or they can not live. Seeds are produced in smaller number, but they are surer of germinating successfully, because of the reserve of food which they carry. They often have the additional advantage of possessing some special means of distribution.

Propagation by Roots.—*Root sprouts* are shoots which spring up around the parent plant from its roots. Cottonwoods, plums, and lilacs are famous for this habit. If the tree has not been grafted, these sprouts will be of the same variety as the parent, and may be taken up and planted. Sprouts in an orchard are a nuisance, however, and trees should be bred which do not have this habit. Blackberries and red raspberries are commonly propagated in this manner.

Fleshy roots of the dahlia, sweet potato, and asparagus grow about the base of the plant in clusters. They are taken up, separated, and

planted. Each root makes one or more plants. In the sweet potato this practice has resulted in the loss of the ability of the plant to produce seed, and all propagation is by this method.

FIG. 203.—Root sprouts of the wild raspberry. The patch maintains itself by sending up sprouts from the roots each spring. The shoot grows the first summer, bears fruit the second and dies down to the ground in the fall. Raspberries are propagated artificially by transplanting these shoots.

Propagation by Stems.—*Rootstocks* are the thickened, underground stems possessed by ferns, cat-tails, blue flags, and many grasses, such as Johnson grass and Bermuda grass. In their underground position rootstocks are protected from mechanical injury, frost, and grazing animals. The Canada thistle owes its reputation as a weed which is difficult to eradicate, to its rootstocks.

Tubers are possessed by the potato and the maderia vine. The tuber is an enlargement at the end of a rootstock. The common forms of the potato no longer produce seed. When seeds are secured and planted, the resulting plants are exceedingly variable. New types may be established by selecting favorable variants. The new type must be propagated by planting the tubers, otherwise the type will be lost.

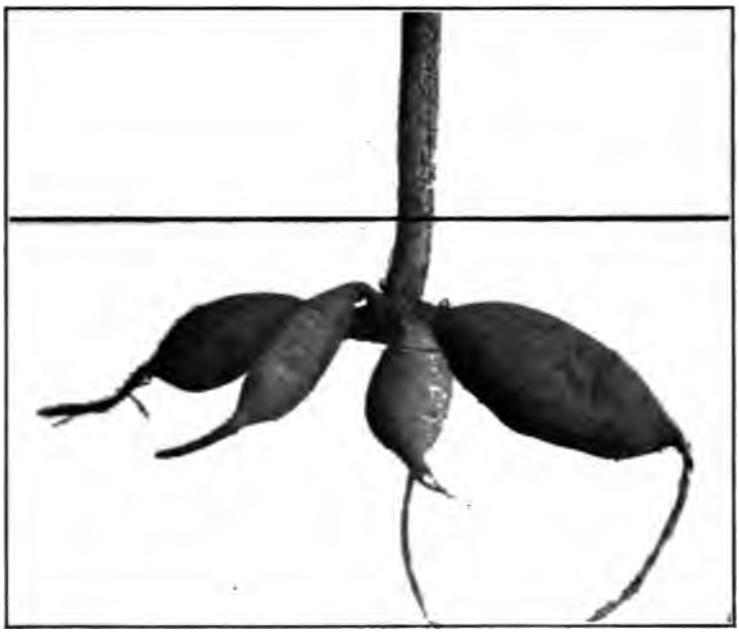


FIG. 204.—Fleshy roots of the dahlia. Each root will make a plant the next season if they are separated and planted.

Bulbs are fleshy buds formed under ground, and are the means of propagating many domestic plants. Lilies often bear buds in the axils of their leaves which are small bulbs, and will grow if an opportunity is given them. These aerial buds are called *bulblets*, or as in the case of the onion, *sets*. Some onions and many domestic lilies have lost the ability to produce any seed at all.

Corms resemble bulbs, but are more solid, being composed of a fleshy, hard stem-base, surrounded by dry scales. They are found in the gladiolus, caladium, and Jack-in-the-pulpit. The gladiolus

FIG. 205.—Tuberous underground stems of the artichoke.

produces many small corms, called *cormels*, around the parent bulb each season. They may in time be able to produce flowers. Both bulbs and corms multiply during the summer, each parent bulb yielding from two to four large specimens which may be planted

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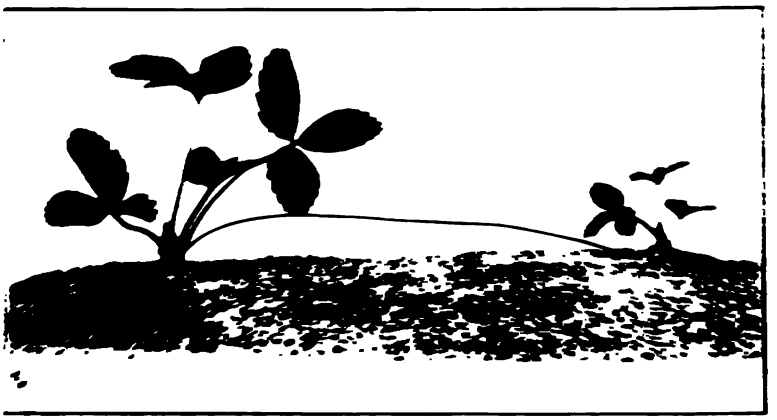

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again the next season. Increase by bulbs and corms is comparatively slow, but sure (see Figs. 65 and 66).

Stolons are slender branches which run out from the parent plant, and take root near by, thus establishing another plant. The strawberry (Fig. 207), a primrose, and the Boston fern are

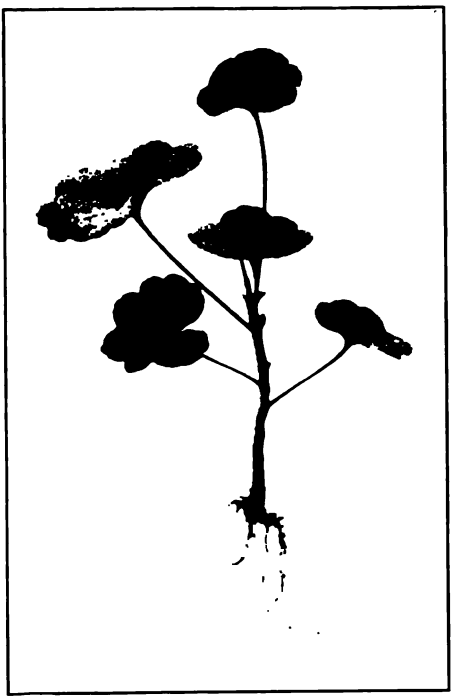

FIG. 208.—A rooted cutting of the geranium. The geranium is one of the easiest of all plants to raise from cuttings.

examples of plants which send out very slender shoots called *runners*. The canes of the black raspberry bend over and take root at their tips toward the end of summer.

Layering is resorted to in multiplying many kinds of vines, especially grape vines and roses. The slender stem is bent over and buried until it takes root. It is then cut off and set out.

Cuttings are made from plants which root easily. Willows, elms, and poplars are well known examples among the trees. When house plants are propagated in this way the cuttings are called *slips*. This is almost exclusively an artificial method, but in nature

FIG. 209.—A well rooted strawberry plant ready to be transplanted. This is the most common method of propagating strawberries. (*Farmers' Bulletin* No. 198.)

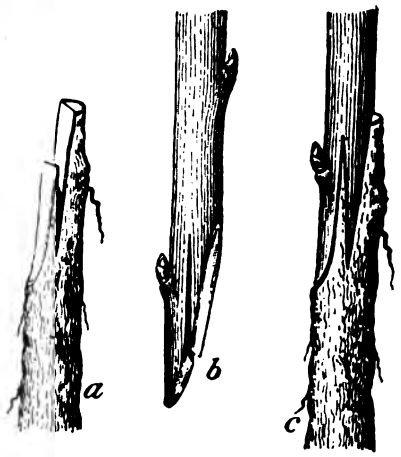

FIG. 210.—Method of making a whip graft. *a*, the stock; *b*, the scion; *c*, the two united. In this case the stock is a root. (*Farmer's Bulletin* No. 157.)

the twigs of the crack willow often take root when broken off by the wind. Sugar cane is propagated entirely by cuttings. Pieces of the canes of the year before are cut in pieces and buried in trenches. They take root and produce the next crop.

Transplanting is another artificial method of propagating many plants,—such as cabbage, tomatoes, peppers, and most all trees, vines, and shrubs. It is resorted to to conserve work and space and to get an earlier start for the plant.

Grafting is resorted to by nurserymen because fruit trees do not breed true from seed. A *scion* is a portion cut from a tree of the desired variety, and is to be grown on a root or stem of another plant called the *stock*. The scion and the stock must be closely related or the graft will not be successful. Apples and pears, or almonds and peaches, or pecans and hickories can be grafted together; but an apple and a hickory can not be successfully united in a graft. Of course all kinds of apples will grow on all other kinds of the same fruit, but some varieties are more adapted to grafting than others.

FIG. 211.—Photograph of a shoot growing from the tip of a leaf of the live-for-ever.

In a graft the scion determines the kind of fruit. The stock contributes the root system. The *whip graft* is most often used to unite scions to roots. The *cleft graft* is used in top grafting,—*i.e.*, cutting back the top of a tree, and by grafting causing it to bear a different variety of fruit. *Budding* consists in inserting a bud, representing a scion, under the bark of the stock. It is very popular with nurserymen.

Propagation by Leaves is of little consequence. The walking fern, some begonias, and live-for-evers are propagated in this way, and resort to this unusual process in nature.

Laboratory Projects.—Divide the class into committees. Let each committee demonstrate a method of plant propagation, and report to the class when their specimens grow. This work should be ready to report on when the class takes up this study.

37. SEEDS AND SEEDLINGS

How does the seed become a plant?

In this chapter we will study the structure of four typical seeds, and note the changes which they pass through in germinating.

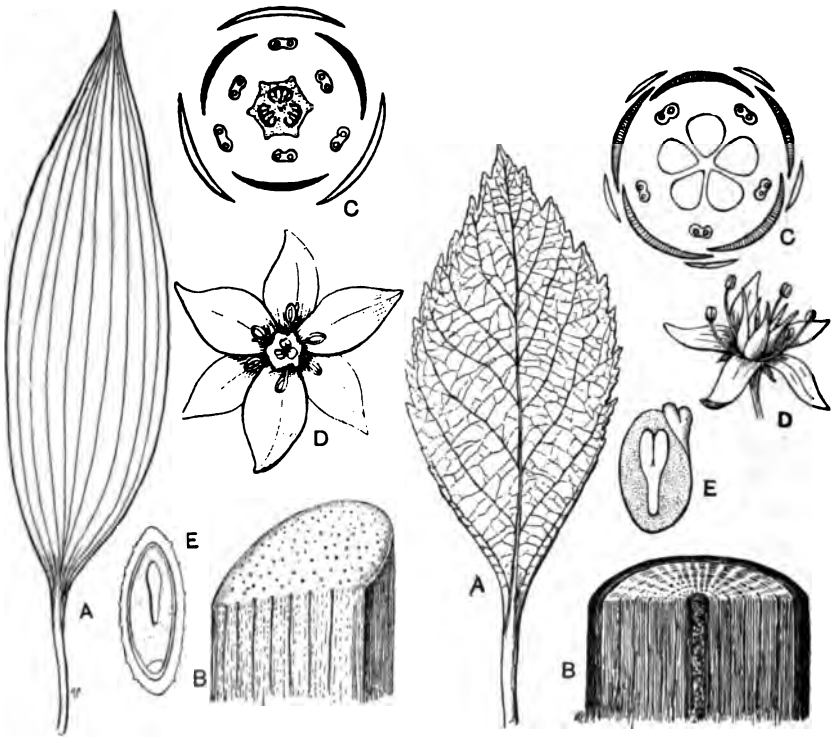

FIG. 212.—Drawings to show the differences between the stems, leaves, flowers, and seeds of monocotyledons and dicotyledons. (*From Gager.*)

Seeds of the flowering plants are of two types—those which have one cotyledon, and those which have two. The seeds of grasses, grains, and lilies are common examples of seeds which have only one cotyledon. They are the seeds of monocotyledonous plants. Refer to the studies on stems, leaves, and flowers; and compare these

structures in monocotyledonous and dicotyledonous plants. Collect these facts in a table like the following and bring to class.

	Monocot	Dicot
Stem.....		
Leaf.....		
Flower.....		
Seed.....		

A grain of corn is a good representative of the monocotyledonous type of seed. It is covered by a tough coat which is the remains of the ovary in which it grew. It is an entire fruit. The greater part of the seed is filled with starch which occupies the broad end of the kernel, and is the endosperm formed by a secondary growth within the embryo sac as described in a previous study.

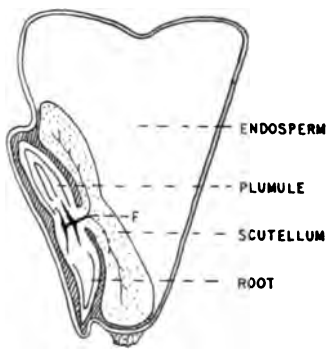

FIG. 213.—A longitudinal section through a germinating grain of corn. *F*, fibrovascular tissue through which the sap passes from the scutellum to the embryo. The scutellum is considered to be the cotyledon, but there is some disagreement in regard to this point among authorities.

A groove is formed along one side of the grain. It is the region in which the embryo is situated. When the seed is soaked in water the embryo enlarges, and the groove swells and becomes a ridge. The young shoot grows out of the end of the ridge toward the broad end of the kernel, and the primary root grows out of the end toward the point of the kernel. Usually two other roots soon appear, and grow in the opposite direction along the surface of the grain. These roots then elongate and branch extensively in establishing the root system of the young plant. The first structure to grow out of the corn grain where the shoot is developing is the *plumule sheath* within which the

plumule makes its appearance. The plumule is the seed-bud which is to develop into the first leaves and young stem of the plant.

The *cotyledon* (seed leaf) of the corn grain is single, and does not rise above the ground when the grain germinates. The *scutellum* is an extension on the side of the embryo which absorbs food for the growing plant from the endosperm. It secretes an enzyme which

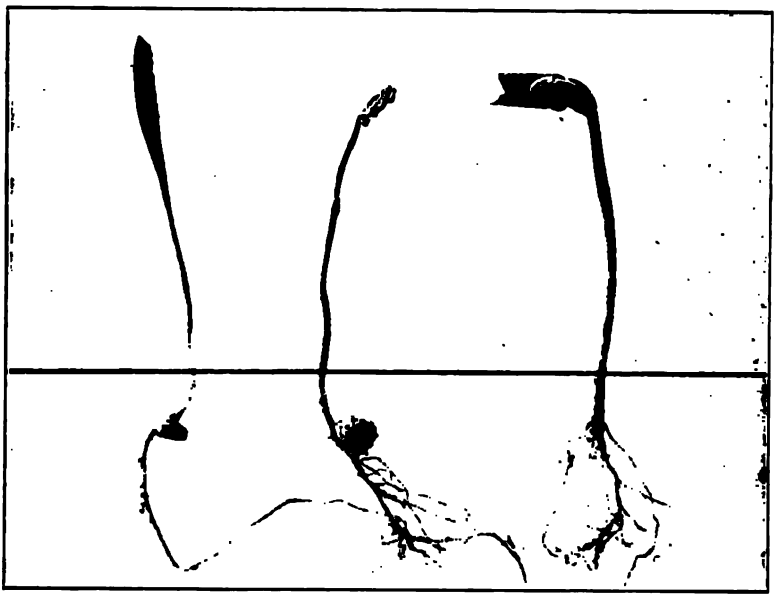

FIG. 214.—Three seedlings. The one to the left is corn; in the center pea; and on the right bean. Note that the cotyledons of the corn and pea seedlings emain in the ground, and those of the bean are lifted up above ground.

changes the starch of the endosperm to a sugar. Starch being insoluable can not be taken up. Glucose is soluble, and is transported through the fibrovascular tissue of the young plant.

The bean seed is a favorite with students in elementary botany as an example of a dicotyledonous seed. The embryo is very large occupying nearly all of the interior of the seed. The endosperm is practically all absorbed by the embryo before the seed is ripe, and,

hence, it does not appear in the ripe seed. The food taken up by the embryo is mostly stored in the cotyledons.

The *testa* and *tegmen* are the outer and inner seed coats respectively. They are the remains of the ovule in which the embryo grew.

The *hilum* is the scar on the concave side of the seed, and marks the place where it was attached to the inside of the pod.

The *micropyle* is a small opening on one side of the hilum, and

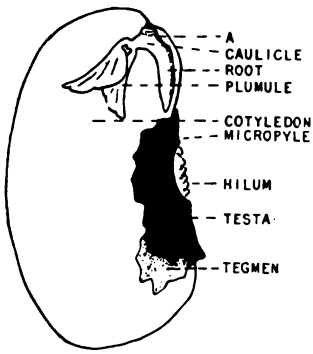

FIG. 215.

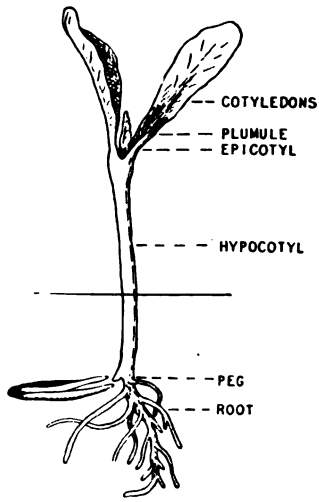

FIG. 216.

FIG. 215.—A soaked seed of the black wax bean with one cotyledon and part of the seed coats removed. *A*, the place where the caulicle is attached to the cotyledons.

FIG. 216.—Drawing of a squash seedling to illustrate the parts of a typical seedling. At this stage of development the upper part of the caulicle is known as the epicotyl, and the lower part as the hypocotyl.

is the place where the pollen tube entered the ovule in fertilizing the egg which developed into the seed.

The *embryo* occupies the interior of the seed, and is composed of the following parts:

The *two cotyledons* are the two halves of the bean. They are the first leaves of the seedling, but in the bean they do not look much like leaves. Between them, at one end, lie the parts that are to become the root and shoot of the young plant.

The *plumule* is the pair of miniature leaves which are attached to the cotyledons by a short stem called the *epicotyl*.

The *hypocotyl* is the continuation of this stem below the cotyledons. The portion next to the cotyledons is called the *caulicle* and the tip is called the *radicle* or *root*. These terms should be memorized in connection with the illustrations.

The pea seed is similar to the bean, but when it sprouts the cotyledons remain in the ground. As a result of this the hypocotyl is

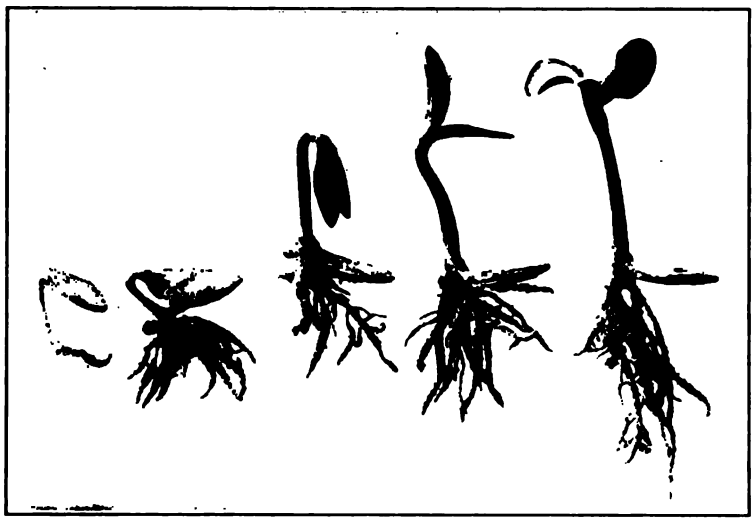

FIG. 217.—Five stages in the development of a squash seedling. Note how the peg pushes off the seed coats. (See also Fig. 216.)

very short and the epicotyl grows very fast to bring the leaves of the plumule to the surface of the ground as soon as possible.

The squash seedling is interesting because of the development of a process called the *peg* on the side of the caulicle. It is used to push off the seed coats. Consult the illustrations and understand how it is done.

In the squash seedling the cotyledons are green, and manufacture starch. They also serve as a storehouse for food in the seed. In the bean the cotyledons rise above the ground, but do little or no photosynthetic work. In the pea the cotyledons serve entirely as a storehouse for food, not even emerging from the ground when germina-

tion takes place. In many seeds,—such as the castor bean seed the food is in the endosperm when the seed is mature; the embryo not having absorbed it before the seed ripened. These seeds have thin cotyledons which are admirably adapted for photosynthesis, respiration, and transpiration. The removal of the food matter from the endosperm, and its storage in the cotyledons is a specialization possessed by the higher groups of the dicotyledons; and renders it more readily available when it is needed in germination. The loss of the cotyledons for photosynthetic work is compensated for by a very rapid appearance of the first pair of plumule leaves.

Laboratory Suggestions.—Appoint committees to plant seeds of the bean, pea, corn, and squash or pumpkin. Study and draw these specimens in the laboratory. *Precautions.*—Make more than one planting, plant in sand or sawdust, keep away from mice, keep warm, and do not fail to water them. Start them two weeks before they are needed.

38. THE CONDITIONS OF GERMINATION AND TROPISMS

Upon what physical condition does germination depend?

It is a well known fact that seeds which are kept in the package do not grow, and those which are planted in the garden usually do; but just what the conditions determining germination are is not so easily understood. The main factors of germination are *water*, *temperature*, *air*, *light*, and *food*.

Water.—Many seeds must attain a certain age and be dried before they will germinate properly. On the other hand, if some seeds are thoroughly dried they will not grow. Seeds which are produced in the spring,—as are those of the elm and maple, germinate at once; and can not withstand much drying.

Water enters the seed by soaking through the seed coats. Some water may enter through the micropyle, but this means of entrance has been overworked in botany classes. The water is taken up by the embryo by osmosis, and growth is stimulated if other conditions are favorable; if they are not, bacterial action may set in, and the seed will decay.

Temperature is the factor in the temperate zone which prevents seeds from germinating in winter or at an improper time in the spring

or autumn. Chemical activity of most kinds is accelerated by an increase in temperature. This is probably due to an increase in molecular vibration. Some seeds will germinate at much lower temperatures than others. A temperature only a little above freezing is sufficient to start germination in peas. Each kind of seed has its ***minimum temperature*** of germination below which it will not sprout, its ***optimum temperature*** at which it germinates best, and its ***maximum temperature*** above which it will not grow. Many crop failures are due to the fact that seeds are planted before the soil is warm enough to start a rapid germination. If in doubt the temperature of the soil should be tested with a thermometer.

FIG. 218.—A vacuum bottle with a thermometer inserted to test the increase in temperature of germinating seeds. Do not pack the seeds in too tight or they will swell and break the bottle.

Air is necessary for the germination of all seeds, but is used in greater quantity by some than by others. The oxygen of the air is taken up by the embryo and used in oxidizing the food material within it. This oxidation produces carbon dioxide and water thus:

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

Glucose + oxygen = carbon dioxide + water

It releases *heat* and *energy of metabolism.* The heat is used to maintain the seed at a temperature higher than that of the soil in which it is, and thus accelerate its germination; and the energy of metabolism is consumed in the physical and chemical activities of the developing embryo. If air is excluded bacterial action may set in, and the seed will decay. Too much water stops or retards germination because it excludes air, but some seeds get enough air from water to germinate. The seeds of most any water plant will serve as an example. It should be remem-

bered in this connection that cold water contains more air in solution than warm water.

Carbon dioxide from the air is of no value to the seedling until green tissue appears and the parts which are to do photosynthetic work are brought into the sunlight; then it is essential to the rapid growth of the young plant, for photosynthesis is about twelve times as extensive in plants as is oxidation.

Light is of little consequence until after the green parts appear. If it is not available then, no green tissue will form; no starch will

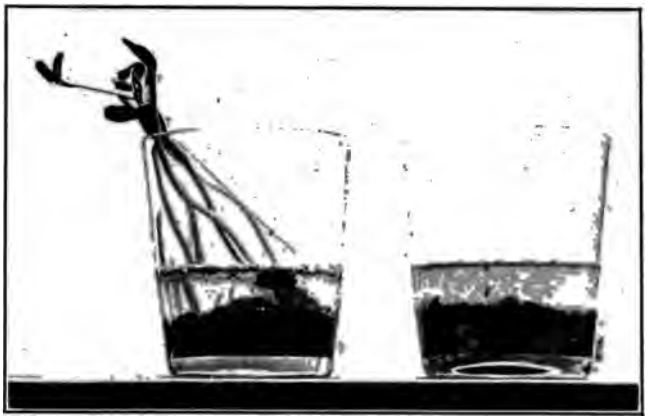

FIG. 219.—Sunflower seeds will sometimes germinate in soil which is under water but pea seeds will decay. Try this experiment.

be made; the plant will remain pale yellow in color, and become long and slender. None of the seedlings of the green plants can live long without light, but some require much less than others. If a seedling which has been kept in darkness is suddenly brought into strong, warm sunlight the tissues will be killed by the action of the light; due to the fact that no chlorophyll has been formed to absorb the rays and thus protect the sensitive protoplasm. The seedlings of clover, alfalfa, and many trees require some shade while they are young for their best growth.

Food enough for germination is stored in some part of the seed, but as soon as the root hairs form on the young root mineral food should be available for the best growth of the seedling. The seed-

lings which grow from large seeds, as a rule, develop faster than those that grow from small seeds. Why?

Tropisms are the movements of plants, in response to some outside force. It is well known that roots grow toward the center of the earth, and that leaves grow in the opposite direction. It is interesting to note that if a seedling is whirled rapidly while it

FIG. 220.—Squash seedlings grown in the dark. Try to determine in the laboratory how long various seedlings are able to live without light.

develops, centrifugal force will overcome gravitation, and the roots will all grow outward from the center of rotation, and the shoots will grow toward the center of rotation. This tendency of plants to respond to gravitation is known as *geotropism* (Gr. *ge* = earth + *trope* = a turning). Roots are said to be *positively geotropic*, and shoots are said to be *negatively geotropic*.

Roots grow toward water. This is partly due to the fact that the ones coming into a moist region will be better fed, and hence will grow more abundantly than those not so well favored. Too much water retards their growth. If the subsoil is too wet, most of the root growth will be near the surface. Then if drouth occurs the

crop will be withered. Why? The tendency of plants to respond to the influence of water is said to be *hydrotropism* (Gr. *hydro* = water + *trope*) (see Fig. 104).

We have seen before that the leaves of plants respond to light influences. This is known as *phototropism* (Gr. *photos* = *light* +

FIG. 221.—An apparatus for whirling seeds rapidly while they germinate. Water strikes against the paddles and rotates the large cork disc, which is suspended on a knitting needle. The seeds are pinned to the cork. The force of the water regulates the speed. This was made in the author's laboratory. Will two boys volunteer to make one for your laboratory?

trope). The leaves of seedlings are especially sensitive to light, and grow toward it. Experiments have been performed to show that roots shun light, but this negative reaction is not so marked as is the positive reaction of the young stem and leaves.

An examination of a bit of soil where weed seedlings are growing in the spring will convince the student that many more seeds sprout than can possibly produce mature plants. Tropisms are large factors in determining which shall live and which shall be crowded out of existence. Those that obtain the best soil pasturage for their roots and the best light and air for their leaves will have the best chance of survival.

FIG. 222.—Phototropism experiment with a bean seedling. The light comes from the left.

Laboratory Suggestions.—The following may be assigned to students as problems to be worked out in groups of two or more.

Will seeds germinate without water? At a low temperature? In the dark? In water? Without soil? Does soaking seeds before they are planted cause them to come up more quickly? How long must squash seeds be removed from the squash and dried before they will grow? Plant some pea seeds in a sealed bottle. Do seeds require air for germination? Fill a small flower pot with corn grains and fasten the saucer over the top with wire. Make it tight. Keep it moist for a few days. Why must germinating seeds exert force?

Appoint committees to illustrate geotropism, hydrotropism, and phototropism. All of this work should be started some time before this study is taken up in class.

Compare the size of seedlings grown from large and small seeds. Which have the best chance to live? Cut the cotyledons from some bean and pea seedlings and compare them with others which have been allowed to retain theirs at the end of a week. How important is the food stored in seeds?

39. THE LIFE HISTORY OF THE FROG

How does the frog develop from the egg?

The female frog lays her eggs in water in the spring of the year. The male deposits sperms over them as they are laid. The sperms

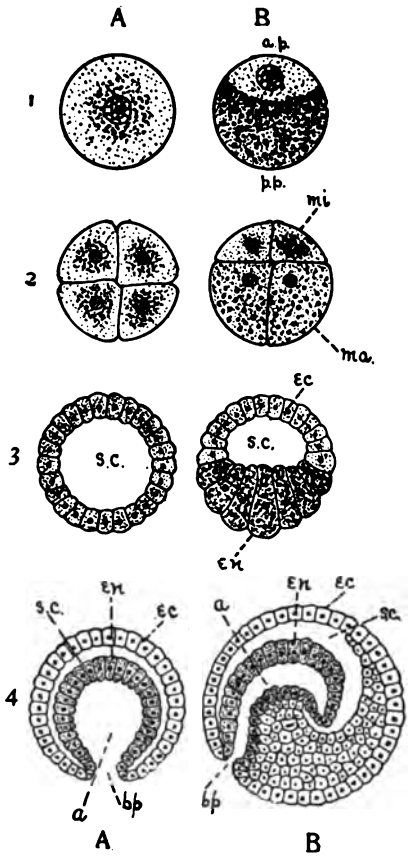

FIG. 223.—Diagrams of the segmentation of the eggs of amphioxus (*A*) and the frog (*B*). The amphioxus egg contains little yolk and forms an ideal gastrula and blastula as shown opposite 3 and 4. The frog's egg contains some yolk which interferes with these processes as shown. *a*, gastrula cavity; *ap*, active pole of egg; *pp*, passive pole; *bp*, blastopore; *ec*, ectoderm; *en*, endoderm; *sc*, cavity of the blastula; *mi*, small active cells; *ma*, large yolk cells. (*From Galloway.*)

and eggs unite, and the development of the egg begins. The formation of an adult frog from a fertilized egg is a wonderful process, and has been very thoroughly worked out by zoologists. We will attempt only a brief account of the process in this study. The illustrations should be studied carefully in connection with the text.

The egg is black on the upper surface, and white below. The black part is composed of much protoplasm, and the white mostly of yolk. The egg cell soon divides perpendicularly into two equal cells. The second division is also perpendicular, and at right angles to the first. The third division is horizontal and at right angles to the first two, but unequal; the cells of the upper half being smaller than the white ones below. As cell division continues a hollow ball is formed, but the lower wall composed of the white cells is much the thicker. This stage is called the *blastula* (little ball). The blastula stage is followed by the *gastrula* (little stomach) stage in which the beginning of the alimentary canal is formed; but the formation of this stage is not easily described for the frog, as it is complicated by the presence of the large yolk cells.

The formation of the gastrula is represented in a very perfect way by amphioxus, the simplest of the vertebrate type of animals. In this form the gastrula stage develops from the blastula very much the same as a hollow rubber ball might be pushed in on one side by forcing the thumb against it until it nearly touches the opposite side. This cavity which surrounds the thumb represents the primitive stomach or gastrula. (See Fig. 223.)

Sponges and **jellyfishes** never get much beyond this stage in development, and this cavity functions as the digestive cavity, although it is modified considerably in some forms, especially sponges. In the frog the gastrula finally elongates and becomes the coiled tube which is the stomach and intestine.

When the gastrula stage is formed the embryo is composed of two layers of cells—an outer layer called *ectoderm*, and an inner one called *endoderm*. The space between these two layers becomes more or less filled with a third layer of cells called *mesoderm*. The skin, nerve cord, parts of the eye and teeth are formed from the ectoderm. The bones, muscles, blood vessels, reproductive organs,

and the covering of the internal organs of the body cavity are derived from the mesoderm. The notochord and the lining of the alimentary canal, liver, pancreas, and lungs are derived from the endoderm.

While the gastrula is completing its development a groove called the *medullary groove* is formed in the black cells. It sinks into the embryo in the region that is to be the back. Folds appear on either side of it which grow up and unite over the groove, thus cutting off a tube parallel to the long axis of the embryo. This tube is the

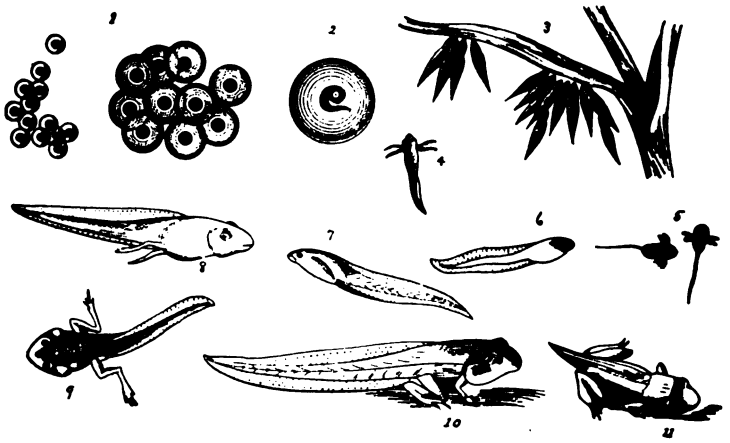

FIG. 224.—The life history of the frog, showing the stages through which it passes in developing from the egg to the adult. (*From Galloway.*)

nerve cord and is thus seen to be of ectodermal origin. The brain is at first merely an enlargement at its anterior end, but soon becomes differentiated into the various parts of the brain.

When the tadpole first begins to move it is black, covered with cilia, blind, and has no mouth. It holds on to objects by means of a sucker on the ventral surface of its anterior end.

The mouth is formed by the infolding of a pit called the *stomodeum.* Three plume-like gills on each side of the head are the respiratory organs. They are soon replaced by internal gills resembling those of fishes. As the internal gills develop the ex-

ternal gills disappear. Finally the internal gills are lost and the animal breathes by means of lungs.

The hind legs are visible before the front legs, but they are really both formed at about the same time. The front legs remain underneath the skin for some time before they are visible externally.

In passing from a tadpole to a frog great changes take place. Water breathing gives place to air breathing; the vegetable diet is changed to a meat diet, and the long, coiled intestine of the tadpole is reduced to the short intestine of the frog; the small mouth becomes a very large one; swimming is replaced by hopping, and the tail is absorbed. The common leopard frog passes from an egg to a frog in one season, but the bullfrog requires two or three seasons to become a frog. The rapidity of growth of a tadpole depends greatly upon the temperature of the water and the quantity and quality of food which it is able to get.

The *principle of recapitulation* is the fact that an animal or plant in passing from the egg to the adult recapitulates or repeats the stages which its ancestors passed through in their development from the first single celled forms of life. In the animals the single celled egg represents the protozoan stage, the gastrula represents the jellyfish stage, and the tadpole of the frog represents the fish stage. This principle must of necessity be very imperfect. Many structures are not represented, some are omitted, and some appear too soon or too late; but the principle has been of great value in tracing the ancestry of the present forms of life. Animals which are closely related have similar life histories. A comparison of the development of embryos is, therefore, a test of relationship.

Laboratory Suggestions.—The author would have preferred to have placed this study at a time when it would be possible to collect living material for study. The life history may be studied in the laboratory from preserved material, models, and charts. Lantern slides may be of great help also. When spring comes make a study of the tadpole in its natural environment.

If Ziegler's models are available, certain types may be sketched by the class.

40. THE LIFE HISTORY OF A BIRD

How does the chick develop from the egg?

The development of the hen's egg has been studied more than that of the egg of any other bird. Most vertebrate animals have

two ovaries, but birds have only one. The right ovary is only a vestige, but the left is very large. When the hen is laying, it appears as shown in Fig. 225. The eggs form near the surface of the ovary, and are surrounded by a fluid. Each egg is separated off from the ovary, as it forms, in a sac called a *follicle*. In this the

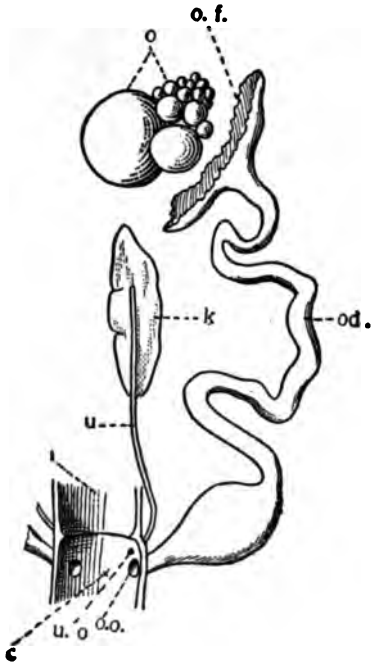

FIG. 225.—Diagram of the reproductive organs of a bird, showing the developing eggs in the ovary at *o*; the oviduct (*od*) into the open end of which (*of*) the eggs pass on their way out through the cloaca (*C*). The kidney is shown at *k*, drained by the ureter (*u*). The oviduct enters the cloaca at *o.o.*, the ureter at *u.o.*, and the large intestine at *i*. Only the left ovary and oviduct are present in birds. (*From Galloway.*)

egg grows to maturity, when it breaks out of the follicle, and passes through the oviduct to the exterior. As it goes it is fertilized by a sperm from the male, receives a covering of food called the white, a shell membrane, and the shell.

The incubation period of the hen's egg is three weeks, that of

song birds is two weeks, and that of water birds is four weeks. During incubation the temperature of the egg is maintained at a point between 100° and 104° F.

We have seen that the frog's egg becomes divided into two equal halves when it divides the first time in segmentation. This type of segmentation is said to be *equal*, and is very common among the invertebrate animals. Because of the large amount of yolk in the hen's egg the first divisions are not complete, and a disc of cells is

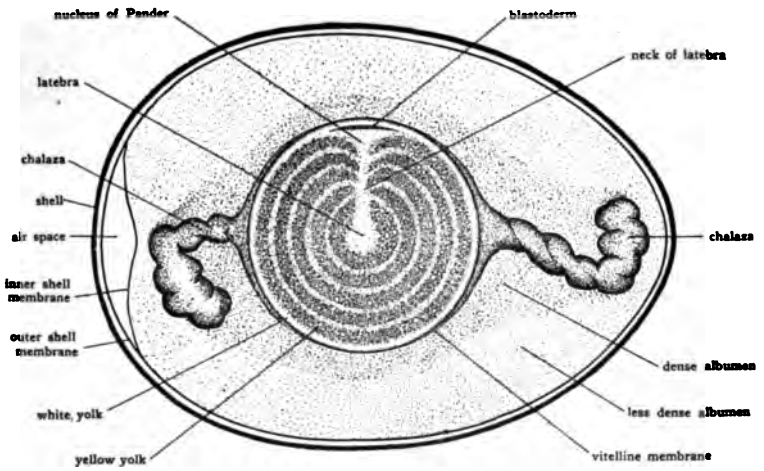

FIG. 226.—Diagram to show the parts of a hen's egg. (*From Patten, after Lillie.*)

formed on the upper surface of the egg. This type of cleavage is said to be *discoid*. The blastula and gastrula stages in the hen's egg are very imperfect because of the presence of the yolk.

The chick embryo develops rapidly, and at the end of 33 hours appears as follows: The neural tube has been formed along the back, and the brain has been divided off into the three divisions,—*forebrain*, *midbrain*, and *hindbrain*. The anlages (beginnings) of the eye and ear appear. The mouth is still separated from the alimentary canal by a membrane. The heart is a bent tube, and the main embryonic arteries and veins are forming. About eighteen muscle segments appear in the mesoderm on either side of the notochord.

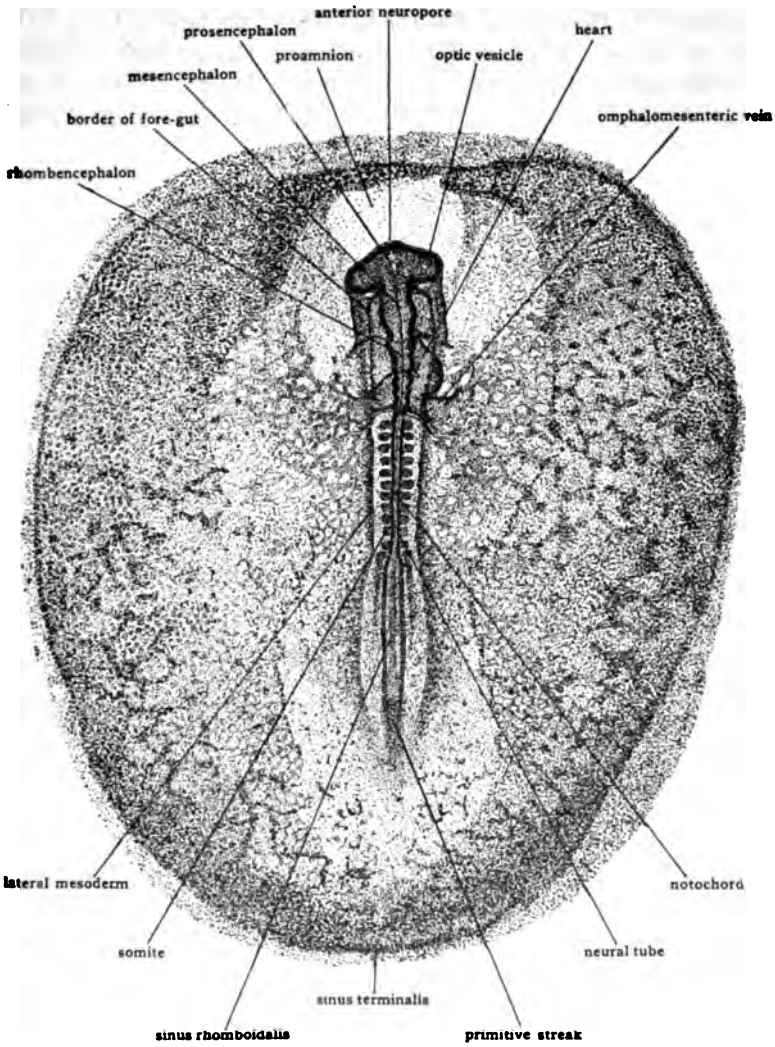

FIG. 227.—Chick embryo after being incubated about 33 hours (*From Patten.*)

At the end of fifty-five hours the embryo is enlarged, and the head has turned to the right so that the left side of the head is toward the yolk of the egg. The lens of the eye has been formed from ectoderm, and has sunk into the anlage of the eyeball. The heart is bent in the form of the letter S, and a circulation which resembles that of a fish

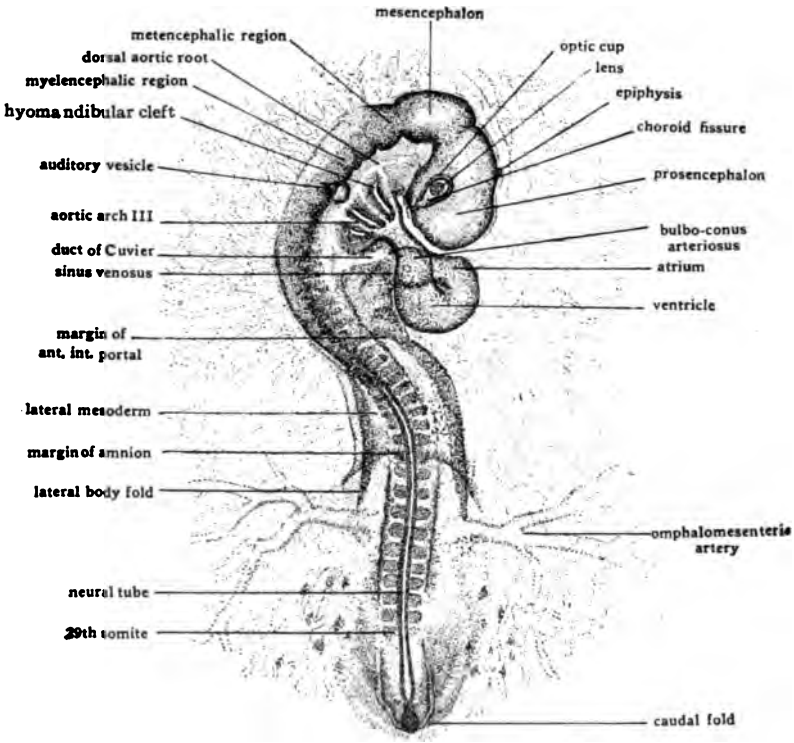

FIG. 228.—Chick embryo after being incubated about 55 hours. (*From Patten.*)

has developed. The *vena cava* has not yet formed, and its work is done by the two *cardinal veins* which persist throughout life in fishes. (The fishes have no vena cava.) Three branchial clefts appear in the region of the neck, and the double aorta sends branches through them very much the same as it does in fishes. These gills are never

of any use to birds, but are there because the ancestors of birds had them. The eighteen muscle segments of the 36 hour embryo have increased to 27.

The ectoderm layer of tissue just in front of the embryo is thrown into an upward projecting fold in the 36 hour embryo. This fold

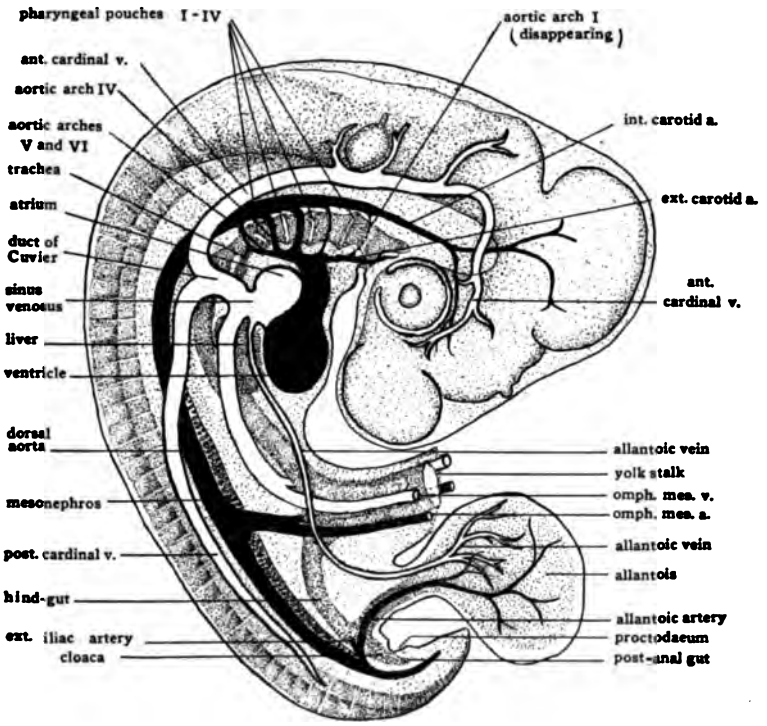

FIG. 229.—Chick embryo about four days old. (*From Patten.*)

is called the *head fold of the amnion*. Just beyond the tail is a similar fold called the *tail fold of the amnion*. These folds grow upward rapidly, and meet over the back of the embryo as shown in the illustration. When they have fused it will be seen that there are two membranes of tissue. The one nearest the embryo is called the *amnion*, and forms a sac around the embryo. It is filled with a fluid

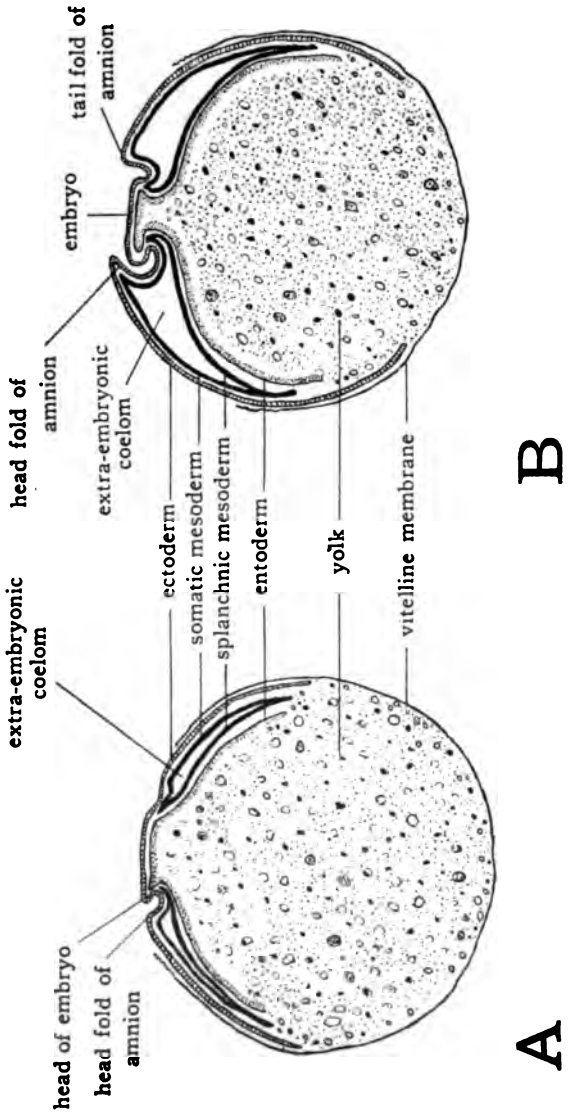
tail fold of amnion
embryo
head fold of amnion
extra-embryonic coelom
ectoderm
somatic mesoderm
splanchnic mesoderm
entoderm
yolk
vitelline membrane
extra-embryonic coelom
head of embryo
head fold of amnion
B
A

FIG. 230.

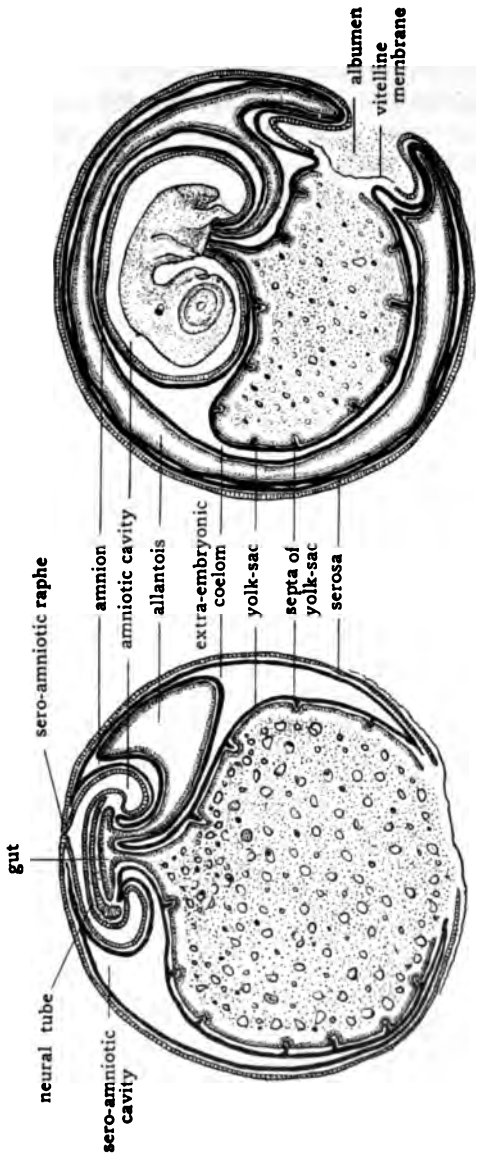

FIG. 230.—Four diagrams to show the development of the allantois, amnion, and yolk-sac. The white of the egg and shell are not shown. The ages of the embryos are as follows: *A*, second day; *B*, third day; *C*, five days; *D*, nine days. (*From Patten.*)

called the *amniotic fluid*. All reptiles, birds, and mammals develop in an amniotic cavity similar to this. The amnion is not possessed by fish or frogs.

The upper layer of the fold described above is the *chorion*, and is of little use in the birds and reptiles, but is present. We will have something to say about it in the next study.

As the embryo develops on the surface of the egg it rises above it, and becomes partly separated from it. The yolk is enclosed in a sac called the *yolk-sac*. This sac is covered with a network of blood vessels which take up the yolk, and carry it to the growing embryo. The yolk-sac is in direct communication with the primitive alimentary canal.

The *allantois* is a structure which grows out from the hind end of the primitive alimentary canal, and hence is lined with endoderm. It develops in the space between the chorion and amnion, and soon covers the yolk-sac. When this occurs the allantois takes over the work of the walls of the yolk-sac which is the extraction of food from the yolk. The allantois is the organ of respiration in reptile and bird embryos. It is of little consequence in the mammals, but occurs.

When the embryo chick is developed, it breaks open the shell of the egg with its beak, absorbs what is left of the yolk-sac and allantois into the abdomen, breaks through the chorion and amnion, and takes up its life in the busy world of living things.

Laboratory Work.—Secure or borrow an incubator and study the life history of the chick from partially developed eggs. Good specimens may be preserved in formalin and used again next year.

41. THE LIFE HISTORY OF A MAMMAL

How does a mammal develop from the egg?

The eggs of mammals are very small, and the yolk-sac is of little importance in the development of the embryo. In the pig the allantois is the most important of the four embryonic membranes. Where it meets the chorion fusion takes place. This part of the chorion comes in contact with the inner wall of the uterus of the parent, and fuses with it. This junction of the allantois and the chorion with the wall of the uterus is called the *placenta* (from

FIG. 231.—Two diagrams to illustrate the formation of the chorion, amnion, allantois, and yolk-sac in one of the lower mammals. *a*, amnion; *al*, alimentary canal; *am. cav.*, amniotic cavity containing the amniotic fluid; *ch*, beginning of the placenta. Note that it is formed from both the allantois and chorion in this type; *s*, chorion (serosa); *so*, body wall; *ys*, yolk stalk. (From Kingsley.)

Gr. = something flat). Through it the embryo gets its food and oxygen and discharges its carbon dioxide and other waste matter by osmosis. The blood of the parent never comes into direct contact with the blood of the embryo.

A diagrammatic representation of the formation of the yolk-sac, amnion, allantois, and chorion in mammals is shown in Fig. 231. The upper figure is a cross section and shows the amniotic folds meeting over the embryo. The lower figure is a longitudinal section at a later stage. The amnion is formed, and the chorion completely encloses the embryo and its membranes. The allantois has grown out to join the chorion to form the placenta.

In some of the higher mammals, including man, the allantois never becomes prominent, but the blood vessels which should pass through it go directly to the chorion through a process called the *body-stalk*.

The only function performed by the allantois in mammals is to carry the blood vessels to the chorion and connect the embryo with the placenta. In the condition described above the allantoic stage is omitted, and a short cut to the chorion is made. Short cuts of this kind are a common thing in embryology, and break up the uniformity of the principle of recapitulation mentioned in a previous chapter.

The main cause of the differences between the embryos of birds and those of mammals is that the eggs of birds develop outside of the body, and those of mammals develop within the body. This necessitates the storing of a large quantity of food in the egg of the bird, whereas in the mammal the food is gotten through a new structure—the placenta. The lowest of the mammalian type of animals,—namely, the kangaroos and opossums, bring forth their young in a very immature condition, and do not have a placenta. The development of the embryos of reptiles in general resembles that of birds. The embryos of the amphibia are tadpoles, and usually live in the water, and get their own food; hence they need no embryonic membranes, and do not have them. Fish embryos usually have rather large yolk-sacs, but lack the other extra embryonic structures.

The **lungs** of vertebrates develop as a simple outgrowth from the ventral side of the esophagus. It elongates, bifurcates, and migrates

to the back of the body-cavity where it divides into many small tubes each with a sac or *alveolus* at its end. Three lobes are formed on the right side and two on the left in man. The lobes remain permanently connected with the esophagus by a tube which becomes the *trachea*. These conditions are shown in Fig. 232.

The **liver** also arises as an outpocketing of the alimentary canal. It takes its origin immediately beneath the stomach region. The *gall bladder* is formed as a secondary outgrowth from the first. The liver never entirely separates from the intestine. The persisting connection becoming the *bile duct* (Fig. 232).

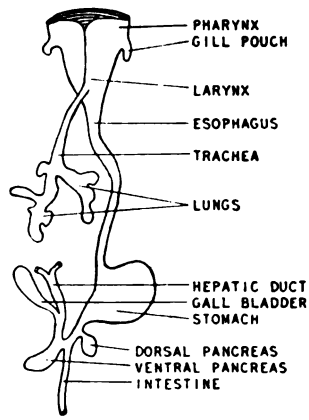

FIG. 232.—Diagram of the anterior end of the alimentary canal of a mammalian embryo to show the origin of the lungs, liver, gall bladder, and pancreas.

The **pancreas** arises as outgrowths from the alimentary canal near that of the liver, but the number and manner of their formation differs considerably in different forms. In man it arises as two out-pocketings,—one ventral, and one dorsal. They fuse together, and the connection of the ventral portion persists as the *pancreatic duct*. These conditions are shown in Fig. 232.

The **kidneys** of vertebrate animals are of three kinds. The simplest type is called the *pronephros*, and is possessed by the lamprey. The second type is called the *mesonephros*, and functions as the kidney of the fishes and amphibians. The third type is called the *metanephros* or true kidney, and functions as the kidney of the reptiles, birds, and mammals. These organs arise in succession from the mesoderm of the back of the embryos. Of course the second and third types do not appear in the embryos of the lamprey, and the third type does not appear in the embryos of fishes and frogs. The higher vertebrates very regularly develop the first and second types only to lose them as the third type appears.

The **eye** is formed by a very complex process. We have seen that the nerve cord and brain are formed from ectoderm by an infolding process. From each side of the brain an outgrowth called the

optic stalk grows toward the side of the head. As it nears the surface of the head, its outer end becomes folded in to form a cup. The

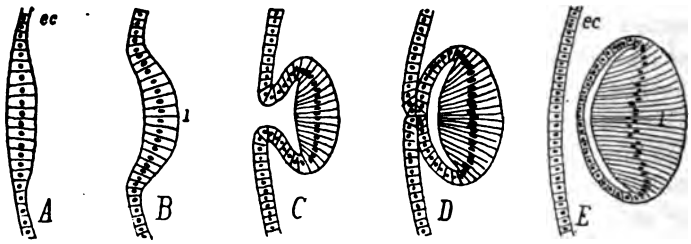

FIG. 233.—A series of diagrams to show how the ectoderm over the optic stalk folds in to form the lens of the eye. (*Kingsley.*)

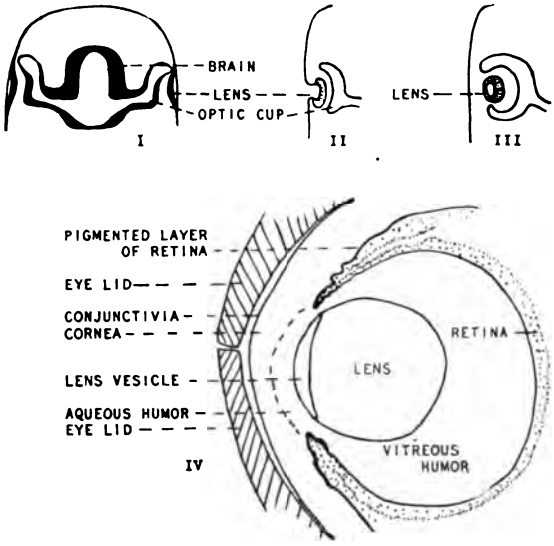

FIG. 234.—A series of diagrams to show the essential stages in the development of the eye. *A*, a cross-section of the head and brain to show how the optic stalks grow out on either side. The ectoderm on the sides of the head is beginning to thicken to form the lenses. *B* and *C* show how the lens is folded into the optic cup. The lower figure is a section through the eye at a later stage. (All four figures are redrawn from the author's laboratory note book made when he was in college.)

lining of the cup becomes the *retina* of the eye, and the remains of the optic stalk is replaced by the *optic nerve*. The *lens* of the eye is

formed by an infolding of the ectoderm of the side of the head as shown in Fig. 233. When it is developed it lies in the cavity of the optic cup, and is separated from the outer surface of the head by an ingrowth of mesodermal tissue. A slit in this mesoderm becomes filled with a fluid (aqueous humor), and forms the anterior chamber of the eye. The lids originate as folds in the ectoderm which come together and fuse. They separate again at birth, or later in some forms, when the eye opens. The eyes of all vertebrates are formed by a process very similar to the one described above, with no exception.

Laboratory Demonstration.—The embryos of cats or rabbits may be secured and kept in the museum cases for observation year after year. Pig embryos for dissection or observation may be secured of the dealers in biological supplies. The general public is woefully ignorant about the simple phenomena of reproduction and the time has come when it is necessary that we treat this subject in a sane way in our schools. It is no more difficult to teach than digestion, and is fully as necessary. The superstitions which pervade the popular mind can not be dispelled in any other way.

UNIT V. PLANT AND ANIMAL BREEDING

Problems of Domestication which have been Solved

42. THE ORIGIN AND VALUE OF DOMESTIC GRAINS

How did man get his domestic grains?

Rice was cultivated in China as early as 2000 B.C. It is the staple grain food of the people of eastern Asia, and is the principal cereal food of two thirds of the human race. It still grows wild in the marshes of Cochin China, and has been modified by man but little since its domestication. Being a marsh plant, man has not destroyed its native habitat and forced the original type into extinction as he has in the case of many of our domestic plants. Rice was probably first domesticated by the Chinese. It spread through India to Babylon and Syria, and appeared in Egypt more than a thousand years after it was introduced into Babylon. It was grown in Italy in 1468. It came to the United States in 1694. A ship from Madagascar entered a South Carolina port in distress, and a bag of rice was left to one of the residents. Rice is now grown in considerable quantity in the southern states. Because of its great value as a food and the ease with which it is prepared for the table, it will, in all probability, be grown much more extensively when its cultivation is better understood throughout the South.

Wheat is the staple grain crop of the people of Europe, Australia, and North and South America. Large quantities of it are raised and consumed in other parts of the world as well. It is the world's most important cereal, and will be raised in greater quantity when machinery for its cultivation becomes more widely used. The United States furnishes about one-fifth of the world's supply.

Wheat belongs to the genus *Triticum* which contains at least seven cultivated species. Common wheat (*T. vulgare*) exists in many varieties, and new ones are constantly being brought forth. The

varieties fall under such general groups as,—bearded, beardless, red, white, black, winter, and spring wheats. Its varieties have been modified to suit the soil and climate of most every agricultural region of the earth. The other six species are less known and may be described as follows:

FIG. 235.—Three common grains. From left to right—oats, rye, rice.

1. **Egyptian wheat** (*T. turgidum*) is a form with a branched head, but in spite of the fact that the head is larger, it does not yield so abundantly as common wheat because it can not grow so thickly. It is not adapted to growth in the United States, but has been much advertised; the claim being made that it originated from some wheat found in the pyramids of Egypt. This claim is a pure fabrication,

for no seed will germinate after it is very old, ten or twelve years being the extreme limit.

2. **Hard wheat** (*T. durum*) is raised in southern Europe and to some extent in this country. It is a spring wheat with a long beard and a hard kernel.

3. **Polish wheat** (*T. polonicum*) is cultivated in eastern Europe.

FIG. 236.—Two forms of common wheat—beardless and bearded.

4. **Spelt** (*T. spelta*) is a primitive form with a husk about each kernel.

5. **Einkorn** (*T. monococcum*) is a form with but one kernel in each spiklet on the sides of the head.

6. **Emmer** (*T. dicoccum*) resembles spelt but has a more compact head and is adapted to growth in arid regions. Besides these

there are several wild grasses which belong to the genus *Triticum*, among which are **quack grass** (*T. repens*) and the **awned wheat grass** (*T. caninum*).

When we consider the large number of species and varieties within the genus *Triticum*, it will be seen that the possibilities of the origin of wheat are numerous. However, the wild ancestor of

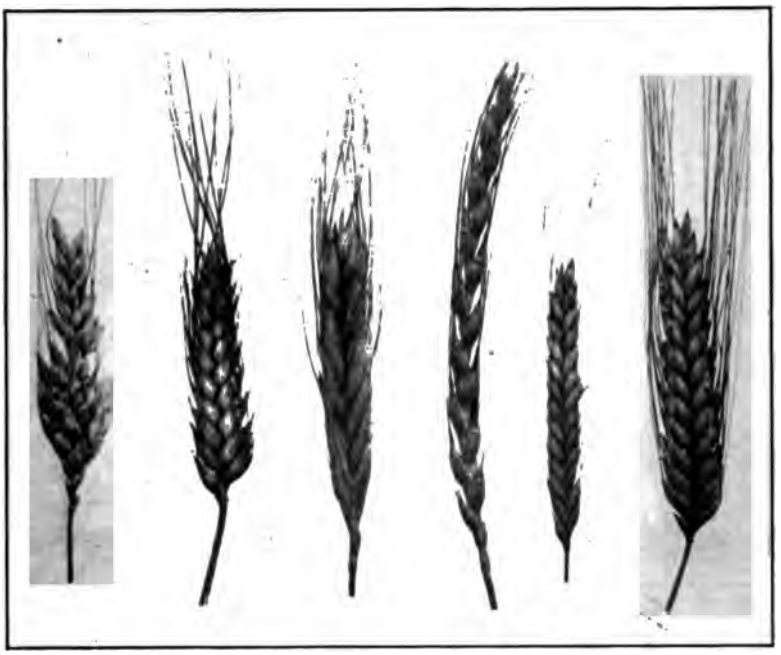

FIG. 237.—Six less common species of wheat. From left to right,—Egyptian wheat, Durum wheat, Polish wheat, spelt, einkorn, emmer.

wheat is not definitely known. A wild form is found in Asia Minor which could have developed into the cultivated form, but we can not be sure that it is the ancestor of wheat. The spelts are the simplest of the cultivated kinds and probably stand close to the ancestral form. Most authorities give Mesopotamia as the place where in all probabilities, the cultivation of wheat began. Good

evidence is at hand to show that it was cultivated in China 4,600 years ago, and that the lake dwellers planted it in Switzerland when Europe was emerging from the stone age. The Egyptians left wheat in the pyramids. It was probably brought to America by the early English settlers soon after 1600. It became the great bread-making cereal of the European and American continents early in the eighteenth century, when it surpassed barley.

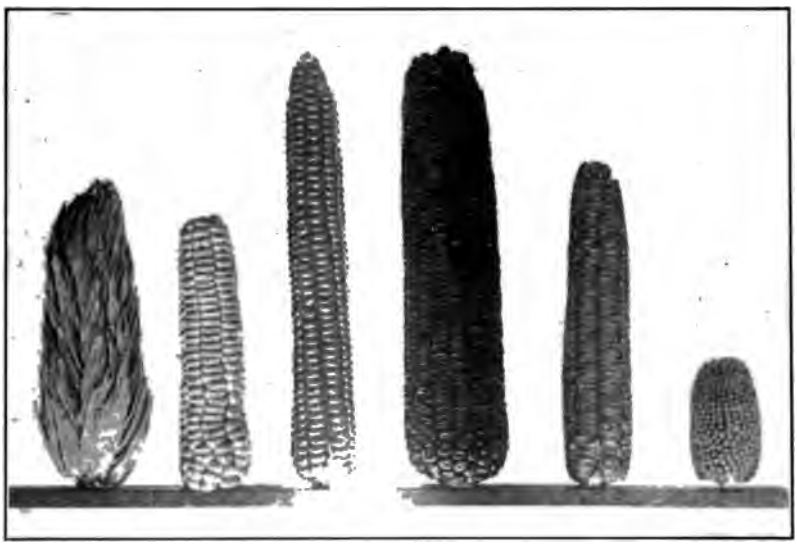

FIG. 238.—The six types of corn. From left to right,—pod corn, soft corn, flint corn, dent corn, sweet corn, pop corn.

Rye (*Secale cereale*) is a new plant among the grains. No name is found for it in the ancient Semetic, Sanskirt, or Chinese languages. It was unknown to the ancient Greeks and Egyptians. It easily escapes and grows wild, showing that it has not been extensively modified by man. Several wild forms are found growing in south-eastern Europe and western Asia, and this is believed to be the place of its origin. It is more hardy than wheat, and is raised on poor soil or in northern countries where wheat does not thrive.

Oats (*Avena sativa*) was not known to the ancient Hebrews or Egyptians, but was cultivated by the Greeks and Romans. It is the staple horse-food of the civilized world today, and in the form of rolled oats is a very important food of man; about 1,000,000 bushels being used in this way each year. The total annual oat crop of the United States is approximately 1,000,000,000 bushels, and is 25% of the world's supply. It is not known where oats were first cultivated, but wild oats grow in many parts of the world. Several closely related forms of variable appearance are found in North America. *Avena fatua* is strikingly like the tame oat, and is a bad weed in the spring wheat fields of the Northwest. The Gartner brothers of England have crossed a wild oat from eastern Asia on the cultivated oat with a view to improving it. Oats readily grow wild and may maintain themselves for several years.

Corn is the greatest of all grains. It was not known to the old world until after the discovery of America. It was grown by the Indians of both North and South America. Several corn-like plants are found wild in the tropical regions of this continent, but it must be remembered in trying to find its ancestor that it is now vastly different from its original form. There is good evidence to show that it formerly bore both pollen and seed in the same flower cluster. Each grain was probably covered by a husk as are the grains of the smaller cereals. A corn of this type has been developed (pod corn), and is grown largely as a curiosity. It is a common thing to find an ear in the tassel, or a tassel in the ear of corn as it grows in the field. Furthermore, corn is exceedingly variable and must be constantly selected to keep up the standard of any one breed. The common varieties of corn are shown in the illustration.

The United States produces over 70% of the world's supply of corn, nearly all of which is consumed within our borders. It is our most important stock food, and promises to become the greatest agricultural crop of the world. It is used by man in the form of cornmeal, glucose, starch, and breakfast foods, but will probably never replace wheat as the basis of flour. Its use as a food for dairy cattle in the form of ensilage is increasing the output of milk and butter per acre in most all sections of the country. Much of the corn raised in the central part of the country is fed to hogs.

Note to Teacher.—Little laboratory work can be done on this study and the three following. Collections of the grains, fruits, and vegetables discussed should be secured and kept in the museum cases for demonstration purposes. It may be safely said that such a collection can never become complete. It should be added to from year to year.

Field Trip.—If possible observe some of the grains as they grow in the field. How and when are they planted? When harvested? What is the value of our grain crops in proportion to other crops.

43. THE ORIGIN AND VALUE OF CULTIVATED FRUITS

How did man get his cultivated fruits?

Although man has domesticated many fine fruits, he has by no means exhausted the possibilities of what can be done in this field. The banana, orange, lemon, and pineapple have but recently become staple crops of the southern states; and the date, fig, and olive are rapidly becoming popular with fruit growers in the same region. Among our wild fruits which show great promise if brought under cultivation are the persimmon, papaw, elderberry, and black haw. Some attempt has been made to improve these and others of our native fruits, and some day they will be grown in commercial orchards as are apples and cherries. The blackberry, strawberry, raspberry, and cranberry have already been greatly improved. So many varieties of the first three have been produced that no matter how fastidious one's taste may be, a color, form, or flavor may be found to suit his fancy. The huckleberry has been improved but little but has shown great promise of improvement under domestication. It varies considerably in the wild state. In your strolls through the swamps, be on the watch for exceptionally fine plants. You may be the discoverer of a new huckleberry.

The apple is our most important fruit. It is grown in a greater number of varieties and throughout a wider range of territory than any other fruit except the plum. Most fruits are luxuries, but the apple is a necessity in the diet of North Americans. It keeps better and has a wider range of uses than any other fruit. Make a list of the uses of the apple.

Both the common apple and the crabapple were domesticated in Europe and taken to America by the early settlers. We have several

FIG. 239.—A branch bearing four fine persimmons.

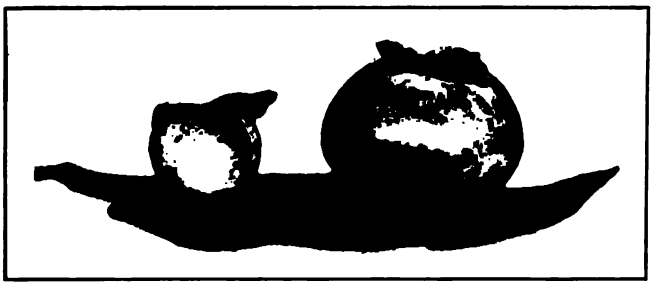

FIG. 240.—Variation among persimmons. These two persimmons are from different trees. Each represents the average size of the fruit on the tree from which it came. If there is this much variation in nature, is it not reasonable to believe that it can be made to vary still more under cultivation; and that some day we shall have a fine domestic persimmon?

fine species of native, wild crabapples, but little use has been made of them in breeding. The Indians made some use of them, but when the white man came they adopted the sweet apple and planted it in

FIG. 241.—Fruit of a seedless, domesticated Chinese persimmon which reaches a diameter of 3½ inches. (*H. H. Hume in the Journal of Heredity.*)

orchards. Some of the old Indian orchards of New York are still in existence.

The apple was probably domesticated more than once in prehistoric times. It still grows wild in Europe except in the extreme north. As is the case with most domestic fruits, it does not breed

true from seed, and when a new type is obtained it must be perpetuated by grafting. For this reason but little permanent progress was made in apple breeding until after grafting was understood. However, the apple will grow from cuttings which produce apples true to type.

FIG. 242.—The black haw, a fruit with a fine flavor and worthy of the attention of the plant breeder.

The plum was domesticated by the Chinese in prehistoric times, and many good varieties were produced. The Latins raised many plums, probably from one of the many native European species. When the Europeans came to America they brought the plum with them and established it in the northeastern part of the United States, but the European plum did not do well in the South, and in this region the native plums were domesticated. So many kinds

grow wild in North America that it has as yet been impossible to properly classify them. Wight in *Bulletin* No. 179, U. S. Dept. of Agriculture lists 23 species. Others have listed many more. The

FIG. 243.—A hybrid blueberry grown by the U. S. Dept. of Agriculture. This cluster was 3¾ in. in diameter. Blueberries, cranberries, and huckleberries all belong to the genus *Vaccinium*. (*Bulletin No.* 334.)

same author in *Bulletin* No. 172 lists 673 different kinds of plums which have originated from the 23 native American species. Only four of these have come from the states east of Michigan and north of Maryland. Most all of them were produced in the states in the

Mississippi basin. Iowa holds the record with 179 kinds to her credit. Burbank crosspollinated various American, European, and Asiatic plums and produced some of the best plums grown anywhere in the world. Most of these are grown in California. America

FIG. 244.—The American wild crabapple.

easily leads the world in the quality and variety of the plums which she has produced.

The peach probably came from Persia. It is not known to grow wild in a native condition anywhere in the world. It is closely related to the almond with which it can be crosspollinated and on which it can be grafted. The almond is variable in the wild state and sometimes produces varieties approaching a poor peach in the

quality of the pulp; furthermore, they both probably came from the same locality. For these reasons it is believed that the peach never grew wild but was developed from the almond.

In 1900 Michigan led all of the states of the Union in peach production with a total of over 8,000,000 trees. The peach can not stand cold winters, and in 1910—due to cold and the ravages of the San Jose scale—the number of trees had been reduced to less than 3,000,000;

FIG. 245.—Stones of peaches and almonds arranged for comparison. On the left is a peach stone and a seed below; in the middle is the hard shelled, bitter almond; and on the right is the soft shelled almond.

and Georgia had taken the lead with over 10,600,000 trees, followed closely by Texas with over 9,700,000 trees. California stood third with over 7,800,000. This indicates that the peach is more successfully grown in the South than in the North; however, hardy varieties of it can be grown in any state in the union, but not with certainty in some of the northern states.

The nectarine is a smooth skinned variety of the peach, and the apricot is a hairy skinned variety of the plum. The nectarine often

develops from the peach by mutation, but the apricot is a definite variety of the plum and probably originated in China.

The grape has been cultivated since prehistoric times. It grows wild in its greatest luxuriance in the part of Asia south of the Caucasus Mountains, and probably spread both east and west from this

FIG. 246.—One of the American wild grapes from which all of the domestic grapes of the eastern United States have sprung.

region. De Candolle,* writing in 1882, says that perhaps 2,000 varieties under domestication have been described.

When the Europeans came to America they found that this grape would not grow here because it was unable to withstand diseases which it acquired from the native American species. Our native species were immune to the harmful effects of these diseases. At

* *Origin of Cultivated Plants*, D. Appleton and Co.

first it was a great disappointment to them, but they soon took to the native American forms of which Bailey lists 22 distinct species and thirteen varieties which grow wild. All of the juicy grapes are of American origin, and those with thick meat have been introduced from Europe. The European grapes are grown in California, but not east of the Rocky Mountains to any extent.

The Catawba grape was found growing wild in North Carolina in 1842. The Concord was produced by Ephraim Bull at Concord, Massachusetts. The following is a quotation from him, written on a tablet marking the original vine which is still alive:

"*I looked about to see what I could see among our wildings. The next best thing to do was to find the best and earliest grape for seed and this I found in an accidental seedling at the foot of the hill. The crop was abundant, ripe in August and of a very good quality for a wild grape. I sowed the seed in the autumn of* 1843. *Among them the Concord was the only one worth saving.*"

Other forms have been found in a similar manner, and from these other types have been developed.

44. THE ORIGIN AND VALUE OF VEGETABLES

How did man get his vegetables?

The cabbage grows wild in the south of England and Ireland. It is also found at various places in the northwestern part of continental Europe. Although it has been raised in many parts of the world for some centuries, it was not known to the ancients. The cabbage is raised in a great many varieties, but the most interesting thing about its breeding is its many relatives. It belongs to the genus *Brassica* which is native to Europe and temperate Asia. *B. alba* is the **common mustard,** *B. campestris* is the **rutabaga** and **turnip,** *B. napus* is **rape,** and *B. oleracea* is the **cabbage. Kohl-rabi, cauliflower, kale,** and **Brussels sprouts** also belong to the group and have probably developed from *B. oleracea.* All of the above forms are very closely related, and we would not have to go very far back in time to find the common ancestor of all of them.

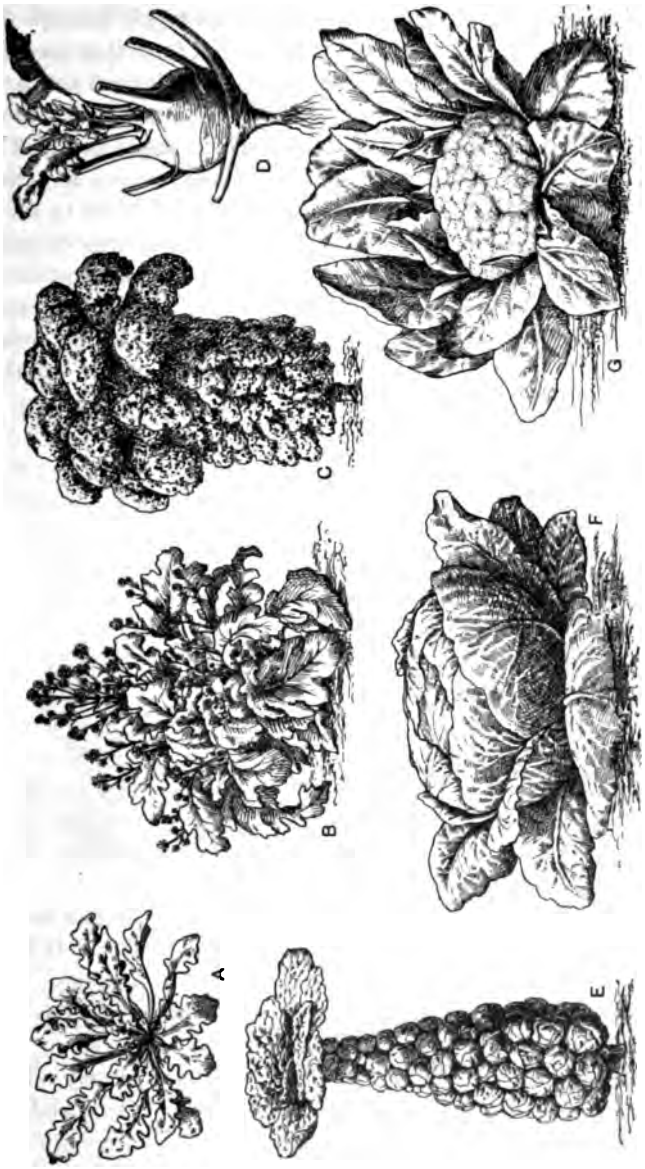

FIG. 247.—The wild cabbage (*A*) and the horticultural varieties which have been developed from it. *B*, broccoli; *C*, kale; *D*, kohlrabi; *E*, brussels sprouts; *F*, cabbage; *G*, cauliflower. What parts of each of these are eaten? (*From Gager.*)

The beet still grows wild in the Canary Islands, all through the Mediterranean region, and eastward. In the red form it is used for its root. In the white form the root is small, and it is used as chard. A giant, red type is called the *mangel* and is used as a stock food. The most remarkable of all beets is the white sugar beet. The Germans wished to become independent of the tropics for their supply of sugar and experimented with carrots and beets to see if they could be utilized for that purpose. The carrot was dropped because of its slow response to selection. At first the beet contained but three or four per cent of sugar. An entire field may now average over fourteen per cent, and individual specimens may be found which average 25 per cent. The sugar beet is extremely variable in sugar content and must be continually selected to keep it up to standard.

Beet Sugar.—The development of the sugar beet has made it possible for temperate countries to produce sugar which is identical with that which is extracted from sugar cane, and is one of the remarkable scientific achievements of the past century. The beet sugar industry began in the United States about 1830. In 1890 the production of beet sugar had risen to 7,748,000 pounds, and in 1909 it totaled 1,024,938,000 pounds.

The tomato is technically a berry, but since it is grown in the vegetable garden we will consider it here. This plant is a newcomer among our domestic species. It is an American plant and probably originated in Peru from where it was taken to Spain. The Europeans raised it in their gardens as an ornamental plant, and supposed it to be poisonous, because most plants in the nightshade family (SOLANACEÆ) to which it belongs are dangerous. This belief delayed its popular use for some time. It has been a common garden plant only within the last hundred years. It lends itself readily to improvement and exists in many varieties. The industry of canning tomatoes and making them into soups and catsup has become great within the past quarter century.

The potato is also an American plant. Several closely related species are found throughout tropical America. De Candolle* sums up a lengthy discussion as follows:—

* *Origin of Cultivated Plants*, D. Appleton & Co.

"1. The potato is still wild in Chili, in a form which is still seen in our cultivated plants.

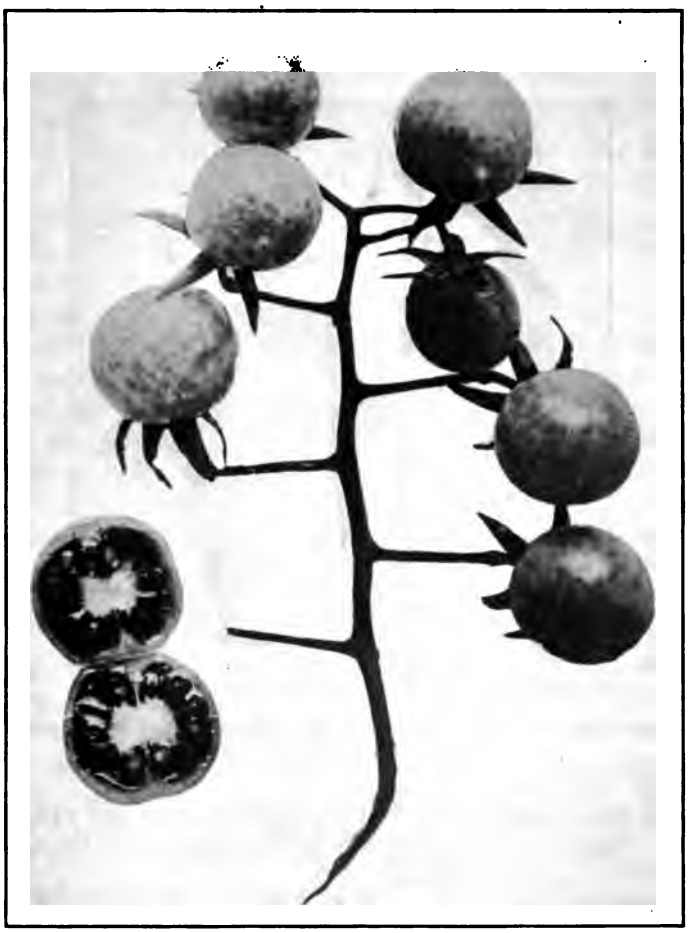

FIG. 248.—Berries of the wild tomato, ancestor of our domestic forms. (*From Chas. H. Gable in the Journal of Heredity.*)

2. It is very doubtful whether its natural home extends to Peru and New Granada.

3. Its cultivation was diffused before the discovery of America from Chili to New Granada.

4. It was introduced, probably in the latter half of the sixteenth century, into that part of the United States now known as Virginia and North Carolina.

FIG. 249.—Two well-shaped tomatoes. Note that there are fewer berries in a cluster than in the wild form.

5. It was imported into Europe between 1580 and 1585, first by the Spaniards, and afterwards by the English, at the time of Raleigh's voyages to Virginia."

It was cultivated extensively in Ireland soon after its introduction, and this has given it its name. It is the staple food of the Irish peasantry today. Next to wheat it is the most important food of the western world. At the time of the American Revolution but two kinds of potatoes were raised in England, a white and a red variety. New kinds are obtained by planting seed from the berries which

grow on the vines, and resemble small, yellow tomatoes. It has been so extensively improved that most varieties have lost the ability to produce seed and are propagated solely by planting the tubers. We now have innumerable varieties of both red and white potatoes, and can have as many as we wish, for the potato is easily modified by breeding.

It should be interesting to note here that the potato and tomato are very closely related. They have been crosspollinated and one grafted upon the other. When a tomato is grafted upon a potato both fruit and tubers may be found on the same plant. When a potato is grafted upon a tomato the tubers may be produced above ground from the base of the potato stem.

The sweet potato belongs to the same genus as the morning-glory (*Ipomea*). It is not at all related to the potato and was named after it because of a similar habit of growth. However, the potato is a a tuber, and the sweet potato is a root.

The sweet potato is grown extensively throughout the southern half of the United States and is used much as is the common potato. Some forms contain much sugar, and when its great variability is considered, it is not improbable that it could have been developed as a source of sugar as was the beet.

There has been much dispute concerning the nativity of this plant. It is not mentioned in literature until after the discovery of America, soon after which it appeared in cultivation in southern Europe, Brazil, China, and some of the islands of the Pacific Ocean. It is certainly not native to Europe, and does not grow wild in a form that can with certainty be identified as the original anywhere. Several wild species which could have produced it are native to South America and the warmer parts of Asia. It is possible that it had a double origin, but the preponderance of the evidence points to Brazil as its place of origin.

45. ORIGIN AND VALUE OF DOMESTIC ANIMALS

How did man get his domestic animals?

The Dog.—Although man has domesticated many plants, he has brought under his control comparatively few animals. Perhaps the

first animal to be domesticated by primitive man was the dog. It crosses readily with all wolves, the jack-all, and the coyote; and has been interbred with these wild forms many times. The fox resembles the dog; but it is not believed to be one of its progenitors. The dogs of the Eskimos are very much like the wolf, and so were the dogs of the Indians. In Europe the breeding of dogs reached a high development; and such types as the Scotch collie, foxhound, greyhound, bloodhound, and bulldog were developed. All of them differ very much from their ancestor, the wolf. In fact, they all differ more from each other than does the Eskimo dog from the wolf. It is a remarkable fact that wolves which have been domesticated often learn to bark like a dog, and drop the habit of barking and assume the howl again upon becoming wild.

The dog is not so essential to man now as in former times. Primitive man used him extensively in hunting and as an article of food. The Eskimos use the dog as a beast of burden to draw their sledges in the snow where the horse can not live. The shepherds and cattle raisers use the dog in herding; but the great distinction which the dog holds over all other domestic animals is that he has been a companion to man from the time when man was a savage until the present day. No other animal, not even the horse, has equaled the dog as a friend of man.

The horse was probably domesticated in Asia. The tarpan is a wild horse found on the steppes of Tartary and eastward to central Asia. It is certainly a horse, but whether it is the ancestor of the horse or whether it is feral (escaped from domestication) has not been settled. The first historical record of the horse comes from Assyria. It shows the rider mounted on a horse which is led by a servant. It seems a rather tame exercise when compared with following the hounds in England or cattle herding on our western plains. The Arabians rode the camel before they did the horse, and the Egyptians probably got their horses from the Assyrians at about the time of the close of the reign of the shepherd kings (1800 or 1900 B. C.).

The nearest relatives of the horse are the Asiatic and African asses, the zebra, and the quagga. The horse breeds with all of these, but the product of the cross is sterile. There is no proven

case of a hybrid horse giving birth to young. The mule is the product of crossing the female horse and the male ass. It lives longer, is healthier, stronger, and will stand more rough usage than the horse. If mules can be made to produce offspring the possibilities of improving the breed are alluring.

The wild ass of Abyssinia was domesticated by the ancient Egyptians. It is very fleet of foot,—outrunning the fastest horses, and in general characteristics far superior to the domestic form, which is the only plant or animal known which has deteriorated under domestication. The ass has never become popular in America.

Cattle were domesticated by the people of southern Asia in prehistoric times. Asiatic cattle, which are called zebus differ from ours in having a hump on the shoulders and in being smaller in size. They are not found wild, but several forms,—such as the gaur, gayal, banteng, yak, and water buffalo are still abundant in the wild state. It is possible that the Asiatic cattle have descended from some of these forms. The yak and water buffalo have been domesticated but have been changed so little that they become feral if allowed to escape.

The European and American cattle are believed to have descended from the great **Auroch** which was hunted by Caesar and Charlemagne in their day, and ranged over the greater part of Europe. It is now extinct except in the hunting parks of Scotland and northern England where it was confined previous to 1220. These "park cattle" are described by Davenport* as being "somewhat smaller than the larger breeds of domestic cattle of to-day. They are of a uniform dirty white color except the ears, muzzles, switch of the tail, and the lower portions of the legs, which range from brown to a brownish red. They are generally horned and in every way resemble common cattle except as to size, color, and disposition, which is very wild. Their identity with the ancient aurochs is almost assured, leaving us to look with confidence upon these wild park cattle as the original stock, out of which European and especially English breeds have been developed."

Most American breeds of cattle are of English parentage and are, therefore, descendants of the "park cattle." The cattle raised in

* *Domestic Animals and Plants*, Ginn & Co.

America may be divided into two classes: those bred for beef and those bred for dairy products. The beef cattle are heavy and hardy but give little milk.

The American bison has been crossed with domestic beef cattle with a view to improving the type in hardiness. The cross is called a "cattalo." The zebu also crosses readily on the European type, and the two forms have been extensively interbred in Italy and Brazil. The zebu hybrid can withstand the heat of the tropics much better than common cattle.

FIG. 250.—The banteng, probable ancestor of zebu cattle. (*From the Journal of Heredity, after the Bureau of Agriculture, Manila.*)

The sheep has been domesticated since an early date and has more wild relatives than any domestic animal except the pig. In fact, there are so many wild sheep especially in Asia that it is impossible to say from what form it originated. It is probable that sheep like cattle have more than one wild ancestor. They have been raised by man for milk, wool, and mutton. The handsomest wild sheep in the world is the bighorn of the Rocky Mountains. However, it has not contributed to the development of the domestic sheep; for the English settlers brought sheep from England at an early date,

Fig. 251.—A zebu bull and cow, both imported from India. (from B. H.

and the sheep raising industry was well established before the western part of the country was developed.

Most wild sheep have horns, and the fact that they frequently occur in domestic breeds as sports is an example of ***reversion,—i.e.***, the occasional appearance of an ancestral character which has otherwise been eliminated by breeding. (See page 307.)

FIG. 252.—A cattalo. This is a hybrid between a bison and an Aberdeen-Angus cow. (*M. M. Boyd, Journal of Heredity.*)

The goat, like the sheep, still has several living wild relatives. They are found from the Pyrenes of Spain to the central plateau of Asia. Domestic goats come from several sources and are named after the place of their origin. Some of them are: the Egyptian goat, the Sudan goat, the Syrian goat, the Kashmir goat from the hair of which Cashmir shawls are made, and the Angora goat. The Angora goat comes from Angora in Asia Minor and was brought to the United States in 1849 by Dr. James B. Davis. More than 1,000,000 Angoras are now raised for their hair, which is called ***mohair***, in the southern and western part of the United States.

Goats are also raised for their mutton and milk. In some parts of Europe and Asia the goat still furnishes the greater part of the milk used by the population. Goat's milk is richer than cow's milk but has a strong taste.

FIG. 253.—The White Mountain sheep of Alaska. Its horns are not so large as those of the big-horn. (*U. S. Dept. of Agriculture.*)

The hog is an animal of great economic importance in America. We are the greatest hog raisers of any nation in the world. Two types are raised,—the bacon hog and the lard hog. Many more of the latter are produced than of the former, because it fattens faster

and more cheaply and gets heavier than the bacon type. Discuss in class the relation of hog raising to the corn crop. What states are the greatest producers of corn? Of hogs? In the Southwest many hogs are raised on alfalfa and fattened on corn.

FIG. 254.—A good type of male Angora goat. His fleece has grown five months since the last shearing. (*Bull. 749, U. S. Dept. of Agriculture.*)

The hog was raised by the Chinese in prehistoric times and probably sprung from some of the wild pigs of that country. The Indian wild boar of southeastern Asia is very similar to the domestic pig and may be its original ancestor. When the hog reached Europe it was freely interbred with the European wild boar which is now

almost extinct except in some of the hunting preserves of Germany. We are reasonably certain that the blood of more than one wild form has contributed to the development of the domestic pig.

The domestication of birds and fish will be discussed in studies 69 and 70.

Suggestions.—Begin making a collection of pictures of our domestic animals and their ancestors, and add to it from time to time.

Make an excursion to a stock farm.

Problems Which are being Solved

46. VARIATION

What are the laws of variation?

It is a matter of common observation that no two living things are ever exactly alike. In a grove of oak trees no two trees will be the same in the arrangement of their branches. The children in a family, even twins, are not alike. This difference in members of the same species is known as *variation* and is a universal biological fact.

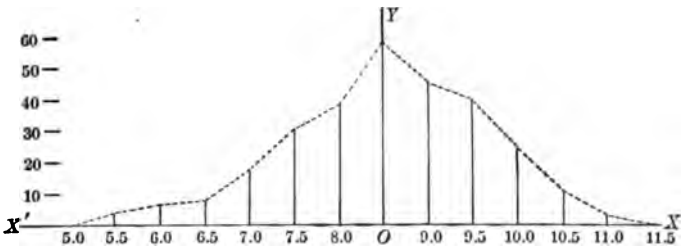

Fig. 255.—The frequency curve for the distribution of ear-length in the 286 ears of corn from Davenport. The length of the ears is written along the bottom line. The number of ears of each length is indicated by the upright lines and by the figures in the column to the left. The mode is a length of 8½ inches and is indicated by the line *YO*. (*Domestic Animals and Plants, Ginn & Co.*)

Variations have been classified under two types. They are *continuous* and *discontinuous*, but some variations are difficult to place definitely under one or the other of the two categories.

Continuous Variations are small variations,—such as the differences between leaves on a tree, difference in length of ears of

corn, or a variation in redness of a ripe apple. These variations differ in number and extent according to the *law of probabilities* as announced by the Belgian anthropologist, Quetelet, in 1846. The law is that there is a mean or *mode* which is the average condition;

FIG. 256.—Two ears of sweet corn. The stalks on which they grew were raised from seed from the same ear. Make a list of all of the ways which you can discover in which they vary. List all differences, no matter how slight they may be. It is a long list.

and from this the variants differ both ways,—*i.e.*, some will possess the character to a greater degree, and some to a smaller degree; and the greater number will resemble the modal type.

Davenport* gives an example of the law of Quetelet for ear

*Domesticated Animals and Plants.

length in corn in which 286 ears were measured. As shown in this table 59 were 8.5 inches long. Thirty-seven were a half inch shorter, and 46 were a half inch longer. Only one was as short as five inches, and only one as long as 11.5 inches. In this case 8.5 is the mode. When the data is assembled in a frequency curve we get a line which ascends to the mode, which is represented by 59 ears, and descends again on the other side.

DISCONTINUOUS VARIATIONS are large variations in which the character varying changes distinctly. They are not so common as the continuous variations and have been the cause of much dispute among biologists. Darwin describes the famous ancon ram as follows: "In few instances new breeds have suddenly originated; thus in 1791 a ram-lamb was born in Massachusetts, having short, crooked legs and a long back, like a turnspit dog. From this one lamb the *otter*, or *ancon*, a semi-monstrous breed, was raised; as these sheep could not leap over the fences it was thought that they would be valuable; but they have been supplanted by merinos, and thus exterminated."

Another case of a discontinuous variation is that of the hornless Herford cattle of Kansas. In 1889 W. W. Guthrie of Atchison, Kansas found a hornless bull calf in his herd. It was not a pure bred Herford, but had some shorthorn blood in it. When it matured and was used in breeding, its calves were, to a remarkable extent, hornless; and a strain of hornless Herfords was developed.

Darwin gives a long list of discontinuous variations in his *Origin of Species*. In 1864 von Kolliker designed a theory which he called *heterogenesis* (Gr. *heteros* = other + Lat. *genere* = to produce) to account for the origin of new species by these variations which have been called rogues, saltations, sports, and mutations by various authors. It very seldom, if ever, happens that an entirely new character arises by discontinuous variation. In most cases some character is reduced, but a character may be enlarged. These variations are apparently more apt to occur when there has been some cross breeding in a previous generation and are, therefore, thought to be Mendelian variations, which will be discussed in the next study.

We will now discuss four special forms of discontinuous variations

which we will term *malformations*, *atavism*, *albinism*, and *bud variation*.

Malformations,—such as six fingers on one hand, extra horns on sheep, hare lip and cleft palate in man are distinct variations and may be caused by (1) something which interferes with the develop-

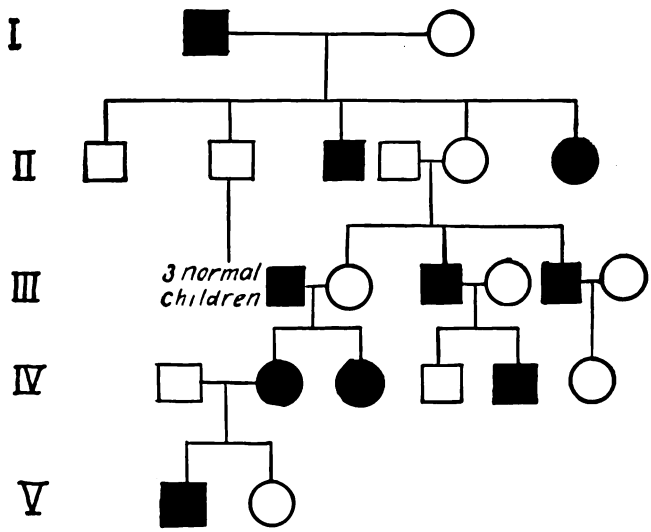

FIG. 257.—Chart showing the history of a case of polydactylism. Note that the defect indicated by black figures runs through the five generations; originating in a man (square) whose wife (circle) was not affected. It appears twice in the second generation and is carried to the third generation by a normal woman. Both of her sons show the defect but her daughter does not. They all marry, and three cases occur in the fourth generation, and one in the fifth up to the time the record was made. (*From "Being Well Born," by Michael F. Guyer. Copyright* 1916. *Used by Special permission of the publishers, The Bobbs-Merrill Company.*)

ment of the embryo in which case they are not inherited, or (2) they may be inherited, and, hence, are due to something which was present before the embryo began its development. Extra fingers or lack of them in man are definitely inherited conditions and reappear again and again in families where they have once appeared.

"Parental influence,"—*i.e.*, the effect of the mind of the mother on the child before birth, as a cause of "birth marks" or mental

characteristics in the child, is a common superstition which has no scientific basis, and should be discouraged.

Atavism is a "throwing back" or reversion to an ancestral condition. Davenport* states that Devon cattle which have descended from the Chillingham cattle (see study No. 45, p. 297) and are solid red in color, in rare instances give birth to offspring with the characteristic markings of their wild ancestors. If pigeons of various kinds are permitted to breed indiscrimnately, the character-

FIG. 258.—A black squirrel and a fox squirrel. The black squirrel is a melanistic variety of the fox squirrel.

istic markings of their wild ancestor appear in the bars on the wing in a few generations. Atavism is a commonly observed phenomenon in many plants and animals. Discuss other examples in class. Crossbreeding seems to increase its frequency of occurrence.

Albinism is the occurrence of white individuals. It may occur in most any kind of animal. White specimens of crows, sparrows, deer, and all varieties of domestic animals are known. The condition is due to a lack of pigment in the feathers or hair, and is strongly inherited if albinos are mated together. **Melanism** is the occurrence of black color in a similar manner.

* *Domestic Animals and Plants.*

Bud variation is a type of variation in which a bud on a plant produces a modification in the leaf, flower, or stem which is distinctly different from the usual type. If the plant can be grafted the variation may be preserved. Many varieties of domestic plants have originated in this way. The peach tree has been known several times to suddenly stop producing peaches and produce nectarines on the whole tree or on one or more branches. The tree may again produce peaches after a year or more. This is perhaps the most striking example of bud variation.

Environment is a direct cause of variation in individuals, but these variations are not inherited and are of no consequence in breeding. As was stated in the study on the honeybee, the only known cause of the differences between worker and queen bees is that they are raised on different food and in different sized cells. The difference in the size and vigor of plants which are raised on good and poor soil is another well known example of the effect of environment on the individual.

Hybrids.—The cause of variation is not known. Most of our information on this subject is of a negative nature. We know of things which do not cause it, but little about its real cause. Weismann worked out a theory which he called *amphimixis*, accounting for variations as being due to the differences in the two parents; but plants and animals which are produced parthenogenetically and have only one parent are also able to vary. However, it is true that if the parents belong to different races,—as the blackberry and the dewberry, the offspring will vary considerably among themselves, and from either parent; and the variations will continue to appear for several generations. Breeding unlike varieties of the same species together is called *hybridizing* and is the chief aid of the plant or animal breeder when he wishes to add something to an old type or produce a new one. Burbank secured most of his many new varieties of plants by hybridizing.

Make a study in the laboratory to illustrate the law of chance which is called the law of Quetelet in biology. It may be done with ears of corn, by counting the number of rings in the bodies of fifty earthworms, by measuring the size of leaves, the height of weeds, the length of peach stones, and in many other ways. It may be done in a mathematical way with inanimate objets, such as checkers, pennies,

buttons, and etc. Throw them up and note which side is up. Keep a record of a large number of trials. Calculate what your results should be and compare with what you get. Plot the curve.

Invite a public spirited insurance agent to make a talk to the class on the operation of the law of chance in regard to human life.

47. HEREDITY

What are the laws of heredity?

The fact that offspring—both of plants and animals—resemble their parents is known as *heredity*. In 1899 a prominent zoologist

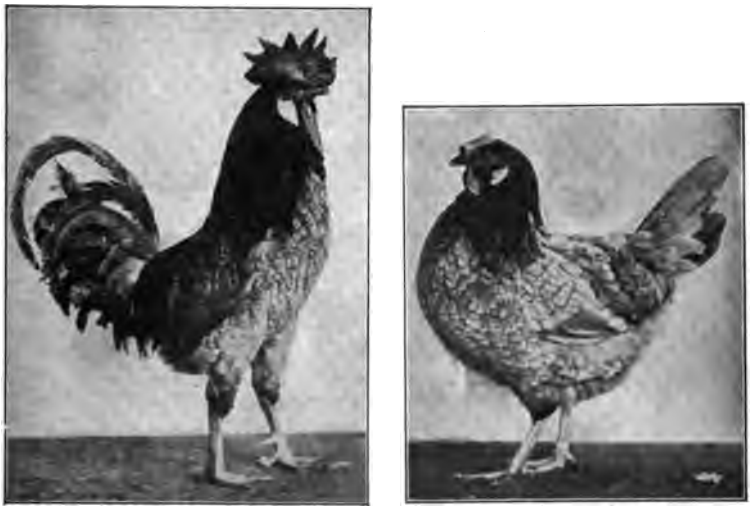

FIG. 259.—A blue Andalusian cock and hen. (*From Jewett's "The Next Generation.*)

wrote, "It is easier to weigh an invisible planet than to measure the force of heredity in a single grain of corn," but so rapid and remarkable has been the advancement of learning concerning heredity that many of its most important mysteries have been reduced to scientific laws.

We will begin our study of the phenomena of heredity by examining the case of the Andalusian fowls. They are much like leghorns and are of three colors,—one being black, another white "splashed"

with a few black feathers, and a so called blue color. The blue ones are not really blue, but are grey or a mixture of black and white. For a long time poultry fanciers tried to breed the blue ones true to type, but they constantly produced offspring some of which were of the black and white types. It was at first thought that if they were selected long enough that this tendency would disappear, but it did not. After years of selective breeding the blues continued to produce just as many blacks and whites as at first, and no more and

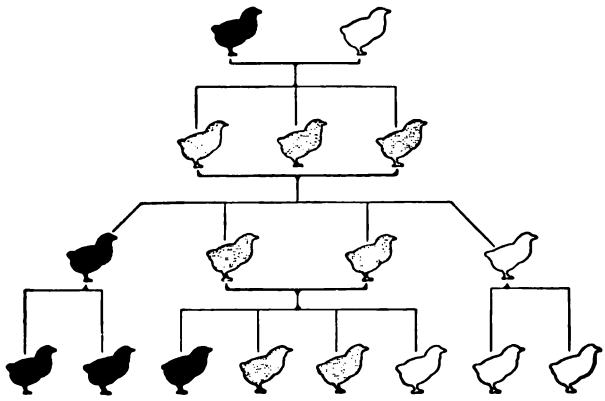

FIG. 260.—Chart showing color inheritance in Andalusian fowls. (*From Jewett's "The Next Generation."*)

no less. The whites always produced whites and nothing else when bred, and the blacks always produced blacks; and it was found by experiment that when white ones were bred to black ones the crosses or hybrids were always blue without a single exception. Therefore, it was concluded that the blue ones were a hybrid type and could not be made to breed true; ***but why should they produce blacks and whites which were absolutely true to type when bred?*** This fact, that the blacks and whites which were produced by the blue hybrids were as pure blooded as the original blacks and whites, was very puzzling.

The Law of Segregation.—The mystery of the blue Andalusian fowl is explained by the *law of segregation* which is that certain characters like black and white, in this case, do not actually blend or

mix in breeding, but only appear to in the first generation. These characters retain their identity and come out in some members of the succeeding generations as pure characters, unaffected by the crossbreeding which has taken place. Like oil and water, they will not mix permanently.

The ¼, ½, ¼ Ratio.—The number of black and white Andalusian fowls which occur when the eggs of blue ones are hatched is a definite ratio to the number of blue ones which are produced. The chart shows this ratio which, of course, holds true only when large numbers are considered. It might not be true if only ten or twelve chicks

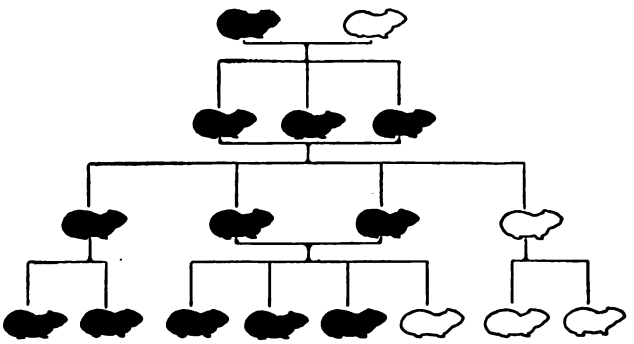

FIG. 261.—Chart showing color inheritance in guinea pigs. (*From Jewett's "The Next Generation."*)

were compared. Study the chart carefully and you will see that the original parents (P) are black and white. The first filial generation (F_1) are blue. The second filial generation (F_2),—*i.e.*, the offspring of F_1, are ¼ black, ½ blue, and ¼ white. In F_2 if the blacks are bred to blacks all of the offspring are black; if the whites are bred to whites all of the offspring are white; and if the blues are bred to blues the ¼, ½, ¼ ratio is again repeated. This ratio will continue to appear as long as blues are bred together.

Problem: What ratio will be obtained when a white and a blue, or a black and blue fowl are mated? See a reference in the library.

The Law of Dominance.—If a black and a white guinea-pig are mated the offspring in the first filial generation (F_1) will all be black

instead of blue as in Andalusian fowls. In this case black is said to be *dominant* to white because it "dominates" over it,— *i.e.*, obscures it completely instead of only partly. In the succeeding generations, if the black-white hybrids are interbred the ratio is ¾ black to ¼ white; but ⅓ of the black ones are pure black and will breed true, while ⅔ of them are hybrids. Thus we see by examining the chart that the only difference between guinea-pigs and Andalusian fowls is that in the case of the guinea-pigs the hybrids are black instead of blue, and it can not be determined which are pure black and which are hybrids until the fact is revealed in breeding in the F_2 generation where the pure blacks breed true, and the hybrids repeat the ¼, ½, ¼ ratio which is only apparently a ¾, ¼ ratio. The *law of dominance* is that when two characters stand in opposition to each other one may completely obliterate the other in appearance in the F_1 generation.

There are many cases which show partial dominance to a greater or less degree, as in smoothness and bearding in wheat. Smoothness is regarded as the dominant character, but often there is a tendency to form a beard in the F_1 generation. Thus there are cases of *complete dominance* as in black and white guinea-pigs, cases of *partial dominance* as in smooth and bearded wheat, and cases of *no dominance* at all as in the blue Andalusian fowl. (See Fig. 236.)

Characters which are obscured by dominant ones in the F_1 generation are said to be *recessive characters*,—*i.e.*, they "receed" in the presence of dominant ones. White is recessive to black in guinea-pigs.

Gregor Mendel's Discovery.—Gregor Mendel was an abbott at Brünn, Czecho-Slovakia. He experimented with peas in his garden and discovered the three laws which have been discussed in this study. The law of segregation, the law of dominance, and the appearance of the ¼, ½, ¼ ratio are known as Mendel's laws, and are considered the most important biological discovery of the past century, with the exception of Darwin's discovery of natural selection, which will be discussed later.

Mendel worked on peas for eight years before announcing his conclusions, and worked with the following characters which are arranged below according to dominance.

Dominant	Recessive
1. Green pod (unripe)	Yellow pod
2. Inflated pod	Constricted pod
3. Tallness	Dwarfed
4. Flowers arranged along the axis of the plant	Flowers bunched at top.
5. Seed skin colored	Seed skin white
6. Cotyledons yellow	Cotyledons green
7. Seed smooth	Seed wrinkled

Mendel's papers were published in 1865 and in 1869. "When he read his papers to the scientific society at Brünn, he himself was

Fig. 262.—Gregor Mendel at the age of forty. (*From Gager.*)

excited and enthusiastic, but he saw plainly enough that those who listened were neither excited nor enthusiastic. Indeed, they hardly seemed even interested, and when the reading was over, Mendel's own excitement was gone. His heart was heavy with disappointment. He had expected so much, yet nothing came of it. After that his papers were simply printed and packed away to gather dust in the Brünn library. And here they stayed, out of sight and out of mind, unheard-of and un-dreamed-of, for thirty-four years. For-

tunately, however, during all these years the library had them in safe keeping."* Mendel died in 1884, before the world recognized the importance of his work.

In 1900 de Vries in Holland, Correns in Germany, and Tschermak in Austria rediscovered Mendel's laws independently; and then the original work of Mendel was found. It is probable that Mendel's work would have received some attention in his day but for the fact that the great discoveries of Darwin concerning the principle of evolution were absorbing the attention of all biologists.

The Method of Inheritance.—The discovery of the way in which inheritance takes place is the most important biological discovery of recent years. The *chromosome* was discussed in the study on *Cell Division and Fertilization.* It will be remembered that in the production of eggs and sperms the number of chromosomes which is normal for any particular animal or plant is reduced by one half, so that the sperm and egg each contain half the number common to the species.

When the sperm and egg fuse in fertilization the normal number is restored. However, in fertilization the chromosomes furnished by the male do not fuse with those furnished by the female, but remain distinct, and retain their identity in the production of eggs and sperms in the next generation. Therefore, if a chromosome from the male carries the determiners for the character black and one from the female carries the determiners for the character white, the two characters will both exist in the F_1 generation, but one may be dominant and obscure the other; and in the F_2 generation they will separate again in one half of the offspring and remain together in the other half, producing dominants. This corresponds with Mendel's laws of inheritance. Can you devise a diagram to show this?

The chromosome has been a favorite subject of study by biologists in recent years, and it may be safely stated now that it is the carrier of the determiners of heredity.

Project.—Can some black and white guinea pigs be kept in the animal cages of the laboratory andbred to illustrate Mendel's laws. Perhaps some member of the class can crossbreed rabbits, chickens, or doves at home. Which one of the three laws can not be illustrated with a small number of offspring?

**F. G. Jewett, The Next Generation*, Ginn and Co.

48. PLANT BREEDING BY SELECTION

How are plants improved by selection?

SELECTION in plant breeding has for its object (1) the improvement of the plant from generation to generation, (2) the fixing or maintaining of a type when once obtained, or (3) the elimination of undesirable stock which is mixed with the form which is being selected; and consists in choosing certain individuals from among many to serve as the parents of the next generation.

Wheat breeding may serve as an example of the method used in plant breeding by selection. In the early part of the nineteenth century Professor La Gasca, of the University of Madrid, visited a wheat farmer named Le Couteur, living on the Isle of Jersey, near the coast of France. In looking over the wheat as it stood in the field, they discovered that twenty three different varieties were growing together on the farm. As a result of this visit Le Couteur decided to try to improve his wheat by selecting the best heads from the best plants to produce his seed for planting. He succeeded in producing several good varieties, and is known as the first scientific breeder of wheat. The variety known as "Bellevue de Talavera" is still grown in France and England. The varieties which he established remained true to type for an indefinitely long time.

Some of the facts which are now known in regard to wheat must be taken into account by anyone who would try to improve an old variety or develop a new one.

1. Wheat that has been grown for many years without selection usually contains many varieties growing together in the same field. These differ in their physical appearance, not only, but in their commercial value as well. These varieties were called *elementary species* by de Vries. An elementary species must grow true to type when it is selected and grown separately.

2. Wheat is self-pollinated, and therefore, it grows true to type even though it has access to pollen from other varieties.

3. Wheat may be cross-pollinated artificially and new varieties established by this method. When so established wheat varieties are subject to the variations characteristic of hybrids in the second and third and future generations, but because of self-pollination

they are more easily *fixed*. By "fixing" a type is meant selecting the type specimens until it breeds true. Some types, such as the blue Andalusian fowl mentioned in a previous study can never be fixed, but wheat is relatively easily fixed, and has a strong tendency to remain so for many generations.

FIG. 263.—Breeding plots of grain which has been cross-pollinated. (*Minn. State Agricultural Exp. Sta.*)

In selecting wheat a large number of the choicest kernels of the variety to be improved are chosen and planted in a plot of ground that has been set aside for the purpose. When the plants have developed, they are examined and only the best are selected. When the heads are ripe, only those from these choice plants are taken. The heads from each plant are put in separate bags and weighed. The next year the seed from the plants giving maximum yields are planted in individual rows; each row containing the seed from only one parent. This process is continued for four or five years, when

the milling tests are run on the product; and if it makes good flour, the grain is sown in the usual way and put on the market.

The person who would improve wheat by selection should not expect too much. The very fact which makes it possible to quickly

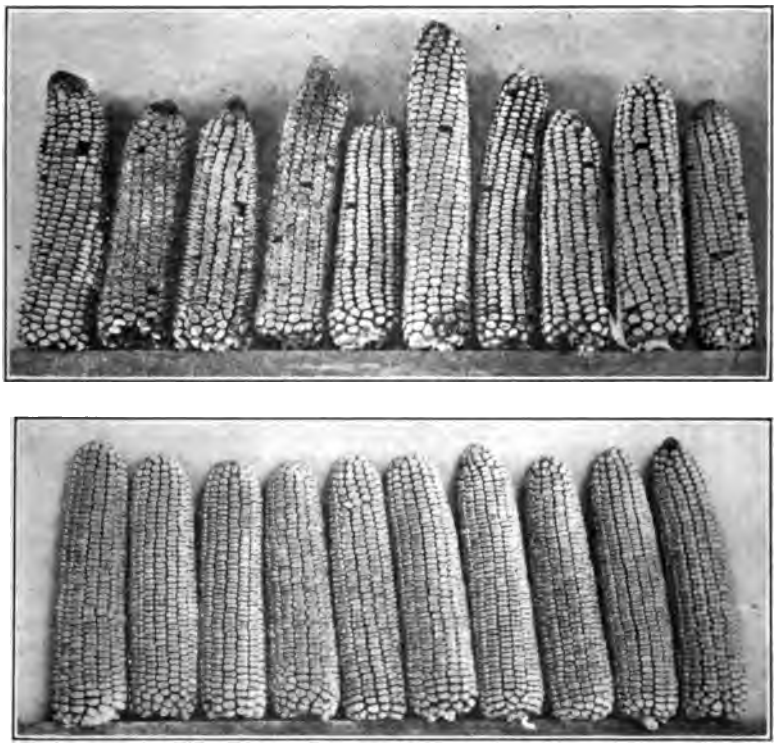

FIG. 264. -Common Wisconsin dent corn which has not been selected above, and improved Wisconsin seed corn below. "The uniformity and generally desirable characteristics have been secured by careful selection, curing, and testing through several years." (*Circular No. 18, College of Agriculture, Madison, Wis.*)

fix a type also makes it difficult to change a certain elementary species beyond a given limit without very long selection. If a distinctly new type is desired it is better to resort to hybridization and then selection. More will be said about this method as applied to other plants in the next study.

Corn breeding will serve as an example of the methods used for a plant that is extremely variable, cross-pollinates, and must be constantly selected to preserve a standard type.

Localities differ as to soil, climate, drainage, etc., hence, corn that does well on one farm may not do well on another even if the farms are located close together. For this reason, if the farmer can spare the time, he should breed his own seed corn from his own fields.

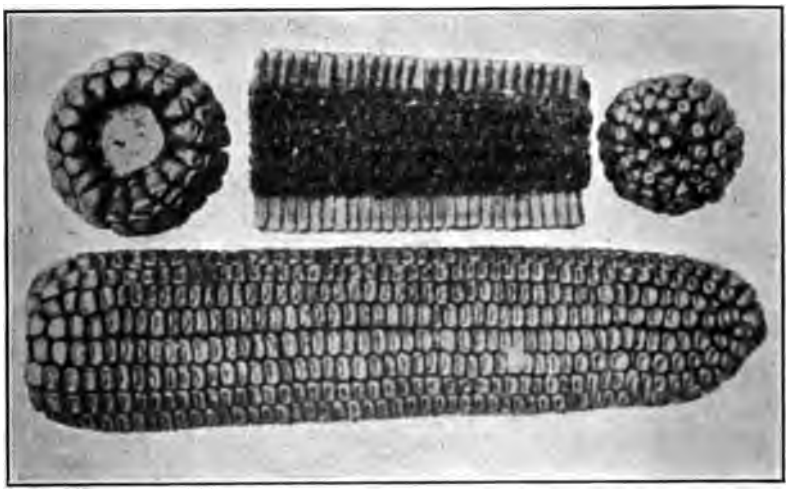

FIG. 265.—The characteristics of a well developed ear of corn. The butts and tips are well filled, the rows are straight, the cob is small, and the seeds are neither too long, too short, or too thick. (*Bull. No.* 653, *U. S. Dept. of Agriculture.*)

When the ears are mature the farmer should go through his field and choose the ears which conform to the type which he has selected to breed for. They should be chosen from hills containing three stalks, and from stalks bearing only one ear, under most circumstances. These ears should be carefully dried and sorted. Only the best should be used. In the spring, before planting time, some seed from each ear should be sprouted to test its germinating qualities. Those failing to show 100% in this test should be discarded.

A special plat of ground which is an average sample of the corn land on the farm should be planted with this choice seed. Each

row should contain seed from only one ear. There is a common belief among corn breeders that if seed corn is pollinated by its own pollen its vigor will be reduced, hence, it is customary to cut the

FIG. 266.—At the time of pollination the silk is growing from the ear and the tassel is shedding pollen. (*From Robbins.*)

tassels from every other row, and save seed from the detasseled rows only. This insures cross-fertilization.

The best ears from the best rows should be planted in plats year after year, and the best rows constantly selected to produce the seed

corn for the farm. It should be noted that the entire row is the unit in selecting, since it is the product of a single ear. Perhaps the worst danger confronting the ambitious corn breeder is to constantly

FIG. 267.—At the end of the season. The two flower clusters of sweet corn. At this season the tassel is dead and brittle.

produce larger and larger ears. Corn with large ears must have a longer growing season and does not ripen with certainty in the northern states. A safe, standard size should be bred for and those that exceed it in size must be discarded by breeders in the North. One

of the most prevalent causes of poor yields is the failure of the corn to ripen before frost.

It is not an exaggeration to say that the average number of bushels raised per acre in the United States can be doubled or even trebled by corn breeding. "It is difficult to realize that the average yield of corn in the United States in 1905, when the total production was the largest in our history, was only 28.8 bushels of shelled corn to the acre. It is still more surprising to know that the average production

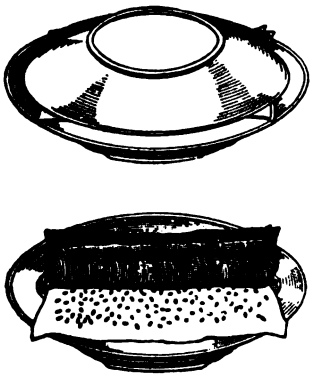

FIG. 268.

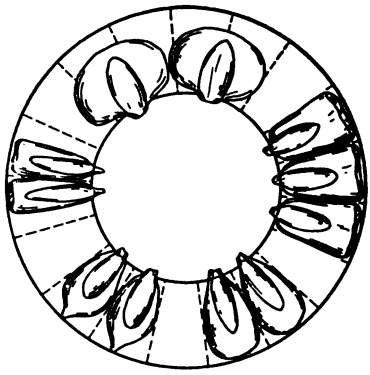

FIG. 269.

FIG. 268.—The plate tester for testing the germinating power of seeds on a small scale. The seeds are placed between two pieces of cloth or blotting paper and moistened. They are then placed between two plates to prevent drying out until they germinate. (*Farmers' Bulletin No.* 939, *U. S. Dept. of Agriculture.*)

FIG. 269.—Variation in the shape of corn grains. Which shape will fill the space around the cob the more completely? (*From Robbins, Mich. Agr. Exp. Sta. Bull.* 34.)

per acre is practically the same to-day as it was forty years ago. In fact, the average yield per acre for the ten years from 1866 to 1875 was 26.7 bushels as compared with 25.2 bushels for the ten years from 1896 to 1905. There are several reasons for this, but the principal reason is gross carelessness in the use of seed of low vitality.

"During the last decade, corn breeders have achieved marked success in the production of improved types of corn, but unless the farmers throughout the United States take better care of their seed corn and test each ear separately, preparatory to planting, the

chances are that the average yield of corn per acre in the United States will not be materially increased." (*Farmer's Bulletin* No. 253, U. S. Department of Agriculture).

The average acre contains 3,556 hills of corn. If each hill contains three stalks, and each stalk bears one 8½ inch ear, the yield will be 120 bushels per acre. If each hill produces two such ears the yield will be eighty bushels per acre. On good soil the yield should approximate eighty bushels per acre as a minimum, and no farmer should be satisfied with less. This is approximately three times the average yield for the country.

Demonstration.—Let two or more students volunteer to demonstrate before the class the method used in testing seed corn for germination. Get the latest bulletin on the subject from your State Department of Agriculture or from Washington, D. C., and use it for reference.

Corn Judging.—If time permits some good corn should be secured and the students should be given an opportunity to judge it using the regulation score cards.

49. PLANT BREEDING BY HYBRIDIZATION

How are plants improved by hybridization?

When an entirely new type of plant or a new combination of characters is desired by plant breeders it is customary to resort to hybridization. Varieties which possess some of the characters desired are secured if possible and are crossbred. If the plant is one which is propagated by vegetative methods a type is easily preserved when once it is obtained, since grafting, slipping, or planting roots or tubers continue its life from year to year; but if it is raised from seed each year the hybrids will vary still more in the F^2 and F_3 generations, and an extensive process of selection must be resorted to to fix the type. The very extensive work of Luther Burbank was based more largely on hybridization as a means of producing great variations and new combinations of characters to select from than upon any other method.

Potato breeding will serve as an example of the method used to breed plants by hybridization. The Rev. C. E. Goodrich of Utica, N. Y. is the father of potato breeding in the United States. The incentive for his work was the widespread occurrence of potato

blight in both this country and Europe, which caused almost a total failure of the crop. His aim was mainly to raise a blight-resistant variety by breeding from wild ones of South America. He secured several varieties from the American consul at Panama, which he supposed came from Chili and Peru. In 1853 a seedling from one of these plants known as the Rough Purple Chili was introduced into cultivation. Goodrich continued his work for

FIG. 270.—Emasculation of a potato flower. *A*, before emasculation. Note the large stamens surrounding the pistil. *B*, the stamens removed and their stumps showing at the base of the pistil. (*Plant Industry Bulletin No.* 195, *U. S. Dept. of Agriculture.*)

several years, and between the years 1849 and 1856 he raised 8,400 seedlings.

In 1870 the Early Ohio, which is perhaps the most extensively raised potato in the United States, was grown by Alfred Rees. It is a third generation seedling of the Rough Purple Chili of Goodrich. Another third generation seedling of the same ancestor is the Burbank potato which was the first valuable plant product given to the world by Luther Burbank.

Potatoes seldom produce any seed. This is a characteristic of many plants which have been long domesticated and which are not

propagated from seed. When potato seed are produced they develop in small "potato balls" which resemble small tomatoes. The plants

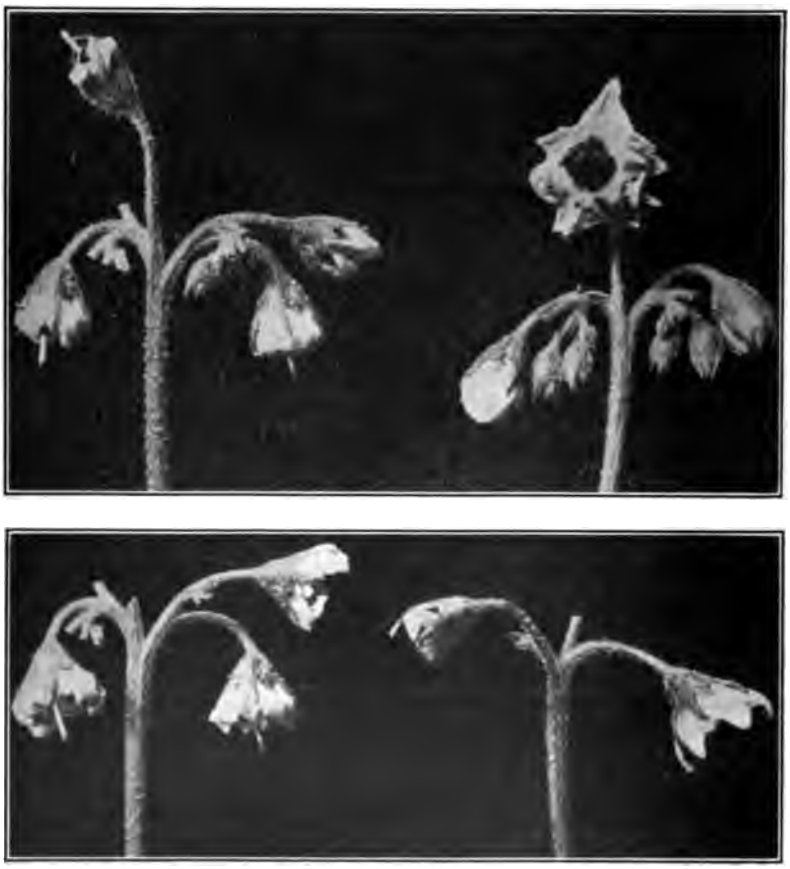

FIG. 271.—Two views of potato flowers showing how they grow. The ones above have some flowers in the proper stage for emasculation and pollination. The ones below have been emasculated and pollinated, and the ones which were too young or too old have been cut away. (*Plant Industry Bulletin No.* 195, *U. S. Dept. of Agriculture.*)

grown from potato seed are extremely variable because of the fact that nearly all domestic potatoes are hybrids and have not been fixed to breed true from seed.

In hybridizing potatoes to secure new types the stamens are removed from the flower to be cross-pollinated when it is a bud, and just before it opens. This is easily done by pushing the petals apart and breaking off the filaments at their base with a sharp pointed forceps.

In one or two days the flower opens and is ready to be pollinated. This is done by picking a flower from the plant chosen to serve as the male parent, and dusting out its pollen on the thumb-nail, from where it is transferred to the pistil of the flower which has had its stamens removed, by simply touching the stigma with the pollen. In hybridization experiments it is customary to keep the pollinated flower covered with a bag both before and after pollination to prevent any other pollen from getting to it; but in the case of potatoes, since they are self-fertilized, and their pollen is not extensively carried by insects, this is probably an unnecessary precaution. Of course only those potatoes which produce seed can be used in this way in breeding experiments, and even these may not set very many seed balls when artificially pollinated; but some seedless varieties produce fertile pollen.

The seed are carefully dried and saved until planting time. They should be planted early in a greenhouse or hotbed and later transplanted to a bed especially prepared for them. The tubers which are formed the first year may be few and small, but if they have good shape and are free from defects they may be saved and planted the next year, when their value will be apparent. By far the great majority of the tubers raised from seed are found to be valueless, but in one case in a thousand something of real worth may be produced.

If any of these hybrids which show merit produce seed, it should be saved and planted for the F_2 variations are usually greater than those of the F_1 generation, furthermore, certain of these hybrids may be cross-pollinated, and, thus, by continued hybridizing and selection the desired type may finally be achieved.

Breeding for immunity to disease is one of the most valuable lines of plant breeding. We will consider three methods,—namely, selection, hybridization, and grafting.

Breeding for disease resistance by *selection* may be illustrated

by what has been done by U. S. Department of Agriculture and independent planters in developing strains of Sea Island Cotton which are resistant to cotton wilt, a fungus disease of the genus *Fusarium*. The soil of certain cotton lands became so infested with the fungus that it was impossible to continue raising the crop, but in

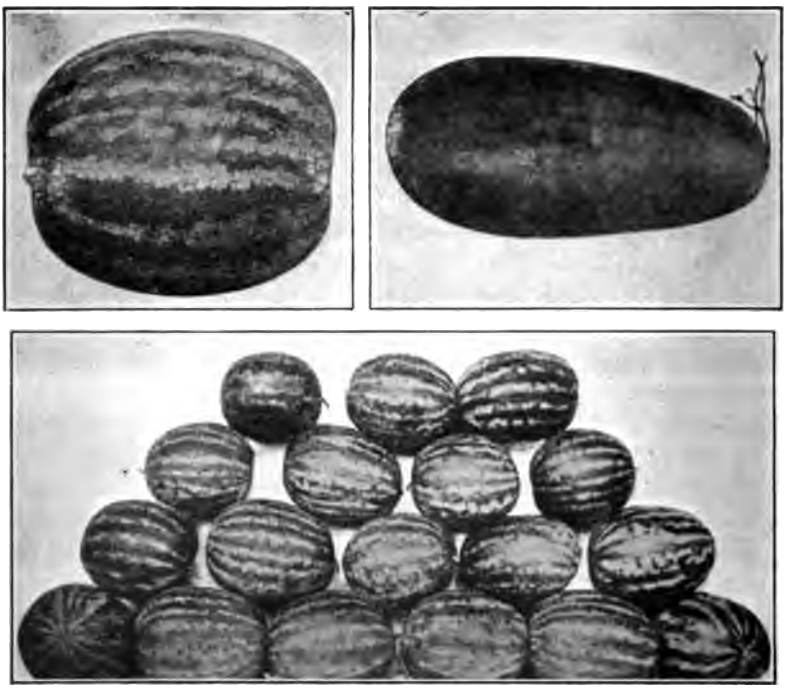

FIG. 272.—An example of plant breeding for disease resistance. The parents are the citron and the watermelon shown above, and the watermelon-citron hybrids of the third generation are shown below. (*From Orton, U. S. Dept. Agriculture.*)

fields which were affected certain individual plants were found which withstood the disease. Seed from these was saved and planted. By continuing this process of selection several strains have been produced which will grow satisfactorily on soil which harbors the fungus.

Breeding for disease resistance by *hybridization* may be illustrated by what has been done to develop a watermelon which will resist wilt, another fungus disease of the genus *Fusarium*. Some 120 different varieties of watermelons were tested, but no individuals were found which showed a sufficient degree of resistance to be used as a basis for selection. However the citron is resistant to the disease, and by crossing a variety of watermelon called the Eden and a citron, hybrids of "wonderful vigor and productiveness" were produced in the F_1 generation. None of these, however, were edible. In the F_2 generation 3,000 or 4,000 plants were raised, and the best ten chosen from which to raise the F_3 generation. By further hybridization with the Eden parent, and after several years of selection, a good melon which is disease resistant was obtained.

Obtaining disease resistance by *grafting* may be illustrated by what has been done in France in order to preserve the vineyards when they were attacked by the imported American aphis, *Phylloxera*. The insects were introduced into Europe with some American grape vines, and threatened to destroy the grapes of the country, for none of them were resistant to the attacks of the parasite. The insects are found on the wild grapes in America, and these and the ones developed from them have considerable ability, which varies in different forms, to withstand the ravages of *Phyllaxera*. Some attempts were made to develop a hybrid between the European and American grapes which would resist the insects, but these efforts were failures.

The insect affects both the roots and leaves of the plant, but the damage to the leaves is of little consequence, hence, by grafting the European grapes on roots of the American varieties which were resistant the grape growing industry in Europe was saved.

50. ANIMAL BREEDING

How does man improve his domestic animals?

In animal breeding, crossbreeding is not resorted to as much as in plant breeding. However, the mule is a hybrid, and is produced by breeding the female horse to the male ass. It is a valuable animal but can not be bred, because it does not produce offspring and probably never can be made to do so. One notable instance of

FIG. 273.—A White Orpington cockerel. Originated by Wm. Cook and Sons. The Orpingtons were produced by crossing several varieties of chickens.

animal breeding by hybridization where the relationship was not so distant as to make the offspring sterile is the production of the Orpington breeds of poultry, which were produced by crossing several breeds. Many breeds of dogs have been produced by systematically crossing various breeds to obtain a wished for combination of characters.

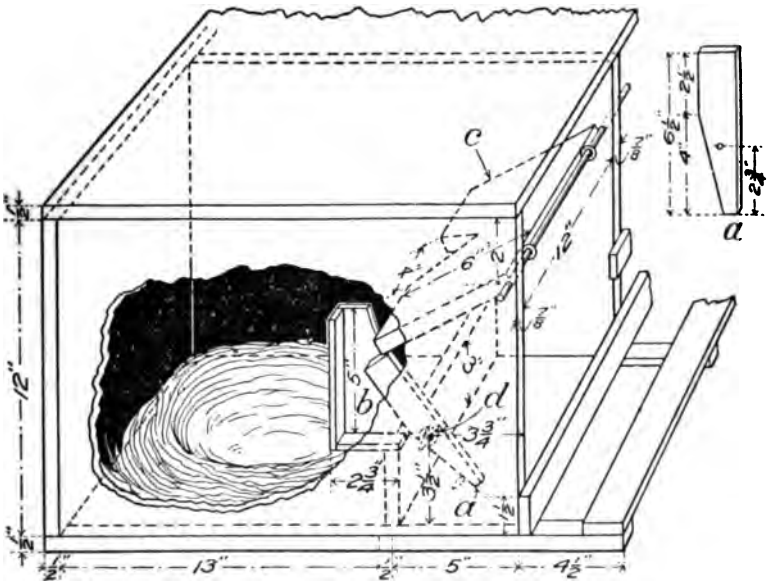

FIG. 274.—A good type of trap nest. (*U. S. Dept. of Agriculture.*)

The method of breeding to which the breeder must constantly resort is selection. Because of the great variety of breeds to choose from, very few new characters or new combinations of old ones are desired in domestic animals now. What is wanted is intensification of certain characters,—such as egg-production in poultry, or quick fattening in hogs. Such characters are often reduced rather than intensified by crossbreeding, and, hence, the modern animal breeder generally has little use for crossbreeds.

Poultry.—Selection among animals must be done very carefully if it is to be of value. It is impossible to estimate by looking at a

hen how many eggs she will lay per year. The only way to find out is to keep a record of the eggs she lays from day to day. This is done by *trap-nesting* which consists in using nests of such a design that only one hen may enter the nest-box at a time, and she can not leave again until she is released. Each hen wears a band on her leg which bears her number, and every egg she lays is credited to her. It has been shown by experiment that it is not necessary to take the record during the summer in order to select the best layers. The winter record is sufficient to determine which hens are the most valuable. By breeding from the best layers, and by using cocks which are bred from championship mothers, the average number of eggs laid by a flock can be raised from year to year. There are many flocks of poultry which do not average 100 eggs per year per hen. It is not profitable to keep such stock. In 1912–1913 the world's record for egg production passed the 300 mark with a record of 303 eggs in one year, made by a crossbreed between a Leghorn and a Barred Plymouth Rock which was bred at the Oregon Agricultural College. This record shows that crossbreeds are not always deficient in special characteristics. If an egg record is to stand it must be made under official supervision in order to guard against error and falsification.

Cattle.—One of the most remarkable examples of animal breeding of modern times is the advances made in dairy cattle breeding. In such breeding the quantity and quality of milk produced and the value of the feed consumed are carefully scored. The milk is tested for the percentage of butter-fat which it contains by treating a measured quantity with sulphuric acid and whirling it in a centrifuge. This causes the fat to separate from the milk so that it can be measured. The test was invented by Professor Babcock of the University of Wisconsin.

Cows have been bred which have produced more than 1,000 pounds of butter-fat per year. At 50¢ per pound the value of the butter would be $500. Professor Fraser of the Unversity of Illinois tested 554 cows from 36 commercial dairy herds and found that the best fourth of the total averaged 301 pounds of butter-fat per year, and the poorest fourth produced 133.5 pounds. He concluded from his experiment that 25 of the better class would yield as much net

profit per year as 1,000 of the poorer ones. How many cows producing 200 pounds of butter-fat per year would it take to equal the record of a 1,000 pound cow? What light does the preceeding record throw on the question, "Why do some farmers get rich, and others stay poor?"

It is not unusual for thousands of dollars to be paid for cows of exceptional individual records and which have good ancestry. Championship bulls have sold for more than $50,000.

"Good judges believe that in the entire country one-fourth of the cows kept for their milk do not pay for their cost of keeping, and nearly a fourth more fail to yield annual profit. As a matter of ordinary business prudence and a condition essential to best results, every dairyman should study the individuality of his cows, keep a sufficient record of quantity and quality of milk product, know approximately the cost of production, and systematically weed out his herd." (*Bulletin* No. 55, U. S. Dep't. of Agriculture.)

The domestication of wild animals is another important phase of animal breeding. The silver fox is a black variety of the red fox, and is an example of melanism which is discussed in Study 46. The hair of the coat is black, tipped with white, giving a silvery effect which is very beautiful. These foxes are born of red parents occasionally and breed nearly true to type when bred together. Because of the great value of their pelts, the experiment of breeding them in pens was tried, and was a success. Now hundreds of them are so bred, and by selective breeding their wild natures have been made more gentle, and the quality of their fur greatly improved. Breeding stock has sold as high as $15,000 per pair. In 1910 some American silver fox breeders sent "to the London sales the finest collection of silver fox pelts that had ever appeared there. This lot, containing 25 pelts, brought an average of $1,386 each, the best one selling for $2,624." (*Bulletin* No. 795, U. S. Dep't. of Agriculture.)

The **raccoon, skunk,** and **muskrat** are also bred in a semi-wild condition for their furs, but little effort has as yet been made to improve the quality of their fur. The following will serve as an example of the possibilities of the business: "The owner of a 1,300-acre tract of marsh, who traps with the aid of his two sons, in two seasons, 1909 and 1910, secured over 12,000 muskrats, which sold

for more than $9,000." (*Bulletin* No. 869, U. S. Dep't. of Agriculture.) With the settling up of the country, and the consequent disappearance of our wild animal life the furs of commerce must come more and more from animals bred in domestication.

Some of the methods used by animal breeders to improve the quality of their stock by controlling matings may be illustrated by describing the main types.

FIG. 275.—A muskrat. The raising of these animals in semidomestication has become a profitable business in recent years.

Line breeding consists in mating the grandparents to the offspring of the second, third, and succeeding generations. This is done to fix and perpetuate the characteristics of the grandparent. Certain animals are noted for their ability to stamp their offspring with their special characteristics. Such animals are said to be *prepotent*, and if the characteristics are highly desirable they are very valuable as *breeders.*

Inbreeding consists in mating closely related animals together. They may be brothers and sisters or cousins. This method has been objected to on the grounds that it tends to deteriorate the vigor of the strain. There is no dependable evidence to support this belief. Some of the best domestic stock has been developed by close inbreeding. However, if bad characteristics are present in the family, inbreeding and line breeding will intensify them. Therefore, unless the stock is perfect these forms of breeding are not entirely safe. Among people, as well as among animals, there is no biological objection to the marriage of cousins if there are no physical or mental defects in the family.

Out breeding consists in breeding animals that are not related or are distantly related, and has been much advocated by breeders in the past because of the belief just referred to that close breeding causes the stock to deteriorate. The scientific breeder of to-day does not consider that out breeding is at all necessary. In fact, bringing in new blood may so break up the inheritance as to interfere with the intensification of a character which is being worked for. It should be remembered also that all stock will deteriorate more or less if it is not constantly selected for the maintainance of the standard type.

Grading is a form of breeding resorted to when it is desired to make over a herd or flock of scrub stock, and give it the characteristics of pure-bred stock. It consists in securing males of some pure-bred variety from which all offspring are raised. The first generation will be half-breeds, the second will be three-fourths pure, and so on. The scrub stock is gradually disposed of, and in a few years the herd will at least look like pure-bred stock. This method of improving stock is often necessary because of the high cost of the first class material. Grading is always to be recommended when pure-bred material can not be bought outright.

51. EUGENICS

How may people be better born?

Whatever may have been man's original condition on earth, he has changed *greatly* from that primitive, ancestral type, and has

diverged from it to form three very different races, each of which has its varieties. It may be that man originated in southern Asia from where the yellow race went north and east, the black race went south, and the white race went west. The American Indian is probably an offshoot from the yellow race. The white peoples constitute a partial albino race, having lost much of the coloring matter in the skin, hair, and eyes.

The fact that man is subject to the same laws of variation and heredity which obtain in the plant and animal world has been known for a long time. The great Greek philosopher, Plato, protested against allowing defective individuals to produce offspring and thus lower the standard of the race.

All defects, either mental or physical, to which man is subject may be classified as either *acquired* or *inherited* as to their cause. If they are acquired they will affect only the one person who has them, and will not be passed on to future generations.[1] If they are inherited they will be passed on from generation to generation as long as the strain of life which possesses them remains in existence.

There are only two fortunate circumstances in this matter. They are that (1) defective strains have a relatively high death rate, and, hence, there is a tendency for their numbers to be reduced; and (2) that it is possible by fortunate matings to completely breed out some defects in a part of the offspring. However, both of these ameliorating tendencies are more than offset by the fact that the birth rate among defective people is extremely high, that the death rate of some classes of defectives is low, and the defectives are to-day multiplying faster than the normal people. It is a lamentable fact that the families which are the best endowed mentally do not average three to four children per family which is the estimated number necessary to maintain the race. Statistics have been compiled to show that university graduates do not adequately maintain their numbers, and the college graduate type must be constantly recruited from the children of nongraduate parents. The failure of a race to produce enough children to successfully maintain itself is known as

[1] Recent investigations show that the effects of certain poisons, such as lead, mercury, phosphorus, and alcohol may be transmitted to even the second or third generation.

race suicide. How do the statistics on births and deaths in your city compare?

INHERITED DEFECTS.—**Physical deformities,** such as humpback, harelip, deformed hands and feet, cleft palate, and tonguetiedness are to a large extent inherited and are known to prevail in certain families. Deafness and blindness may be either inherited or acquired.

Bacterial diseases, such as tuberculosis, syphilis, and pneumonia are not inherited; but *a weakened resistance to the disease is inherited,* and if the disease occurs in a family the well members are especially apt to take it because of the increased opportunity for infection to take place.

Insanity, paralysis, and **feeble-mindedness** are the worst forms of inherited defects because they are elusive and difficult to detect in many cases until after the period of childhood has passed. All forms of insanity are not inherited, but most varieties are. Feeble-mindedness is a recessive, Mendellian character and follows the Mendellian ratio in inheritance. If both parents are feeble-minded all of their children will be feeble-minded. Epilepsy is known to run in certain families and is due to an inherited defective nervous system.

Mr. Hastings H. Hart, Director of the Department of Child Helping of the Russel Sage Foundation, writing under date of May 24, 1913, says that there are 67,000 feeble-minded persons cared for in institutions in the United States distributed approximately as follows: In institutions for the feeble-minded, 20,000; in alms houses, 16,000; in hospitals for the insane, 5,000; in prisons and reformatories, 26,000. A bulletin of the U. S. Bureau of the Census, 1914, gives an estimate that not over one tenth of the feeble-minded are in institutions. These estimates would place the number of feeble-minded in the United States at 670,000, nine tenths of which are without institutional care and *are free to reproduce their kind.* For the past hundred years we have been building more and more and more institutions for the care of these unfortunate people, and the facilities are still entirely inadequate. Nearly every state institution in the country is full to overflowing, yet the remedy for all this is very simple. *If we can prevent them from breeding in a few generations*

there will be few of them. This is certainly an altruistic and merciful thing to do.

The methods of saving us from an over production of defectives group themselves under four heads.

1. Our immigration laws must be improved so as not to admit any defectives or relatives of defectives.

2. The present method of isolating only ten per cent of our defectives must be improved so that at least ninety per cent of them are isolated and prevented from producing another generation like themselves.

3. Those which cannot be kept in institutions must be sterilized. Such an operation can be performed so that it has no bad effects on the patient.

4. Education, both of those affected and of the gneral epublic concerning the principles of eugenics, should be everywhere encouraged.

Have reports given on the following: *The Kallikak Family* by Goddard, the *Zeros* by Poellman, *Noteworthy Families* by Galton, *The Heredity of Richard Roe by* Jordan, and by all means see Mr. Winship's account of the descendants of Jonathan Edwards.

In the famous Jukes family of defectives 1,200 descendants have been traced. It includes 310 professional paupers, 300 deaths in infancy, 440 physical wrecks from debauchery, 50 immoral women, 60 habitual thieves, 7 murderers, and 130 other criminals. At the time the record was made this family had cost the State of New York $1,250,000 for the care of its defective progeny. All this would not have been if the original ancestor had been prevented from producing offspring. We have reduced the breeding of plants and animals to a very efficient science, but have done practically nothing until recently to improve the human race from the standpoint of eugenics.

"Eugenics is the study of the agencies under social control, that may improve or impair the racial qualities of future generations, either physically or mentally" (Galton). It has two fundamental purposes. One is to reduce the number of the unfit by preventing them from being born. The other is to encourage a greater production of the fit in so far as this is possible.

One of the reasons why Greece, Rome, and the other great nations of antiquity perished is that they violated the principles of eugenics. If our nation is to live its people must be of the best, and their blood must not be contaminated by that of the unfit. What is your state doing to improve the next generation?

52. EUTHENICS

How may the race be improved by improving its environment?

If America is to survive as a first class nation it is not enough that we strive to improve its people by eugenics alone. Inheritance counts for much, and a good inheritance is essential to a successful life; but good inheritance avails little if the environment is not also good. The effort to elevate the race by improving the environment in known as *euthenics*, and is fully as important in our civic life as eugenics. Space does not permit us to more than call attention to some of the significant phases of the problem.

The Home.—Euthenics begins with the home. The home-life of our boys and girls must be of the best. The child who is raised in the crowded slums of our large cities is greatly handicapped. The city which permits filth and dirt to accumulate around poorly built tenement houses is sowing seeds for a harvest of boys and girls which will cost it dearly in its hospitals and police courts. No city should permit poorly lighted, heated, and ventilated tenement houses to be built.

It is especially necessary that all bedrooms be properly ventilated. About one third of a person's life is spent in sleep during which time the purest air obtainable should be had.

Every boy and girl should take pride in the home. It should be seen to that the lawns and flower-beds are kept in proper order. Trees should be planted for both shade and beauty, and they should be properly cared for. They should be properly trimmed, and kept free from insect pests and disease. No city can be beautiful without beautiful lawns and trees. The trees are often cared for by the city department of forestry. Has your city such a department? Has your city a law compelling property owners to plant trees along the street? Make a census of the city and report the number and condition of the trees. What should be done about it?

The School.—Have you a school physician or a school nurse? What are adenoids? Have a report given on them. All school children should be inspected at least once a year for adenoids, poor teeth, defective eye-sight, defective hearing, and general health. These defects must be remedied while the child is young if they are to be remedied at all. Has your class been inspected this year?

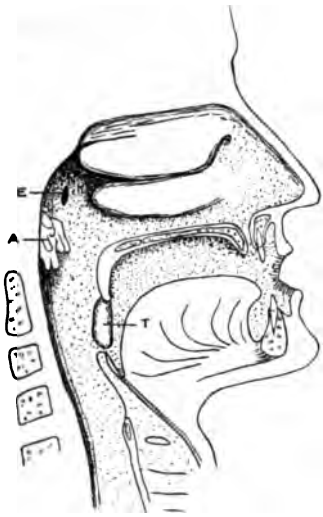

FIG. 276.

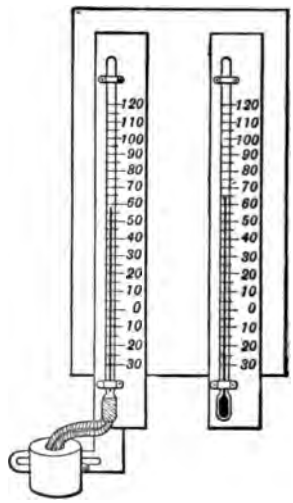

FIG. 277.

FIG. 276.—Diagram of the throat and nasal passages to show the location of adenoids and tonsils. A, adenoids; E, opening of Eustachian tube to ear; T, tonsil.

FIG. 277.—A hygrometer for taking daily readings to determine the amount of moisture in the school room. Will some students volunteer to take turns at keeping a record and report to the principal from time to time? In cold weather, in winter, frost will form on the windows if too high a humidity is maintained. (*From Duff.*)

If not can you interest your superintendent and school board in regard to this important duty? Do not permit the excuse that there is no money available. Neglect is more costly in both money and poor health than present expenditure can possibly be. We are the richest nation in the world. Surely we can afford the money necessary to save the health of our children. In most schools 25% of the children are suffering from adenoids, poor sight, hearing,

or teeth; and in some schools the number is as high as 50%. Many students who are considered backward become as bright as any when these defects are remedied.

Is the lighting, heating, and ventilation in your school perfect? Discuss these three problems in class as long as you wish. They are very important. Influenza may be caused by excessive dryness of the air in buildings in winter. Dryness causes congestion of the mucous membranes of the nose and throat, and gives the bacteria an opportunity to develop. The relative humidity of the school room should not be below 50% in winter. Do you determine the amount of moisture in the building every day? If you do not, will you do it from now on? Authorities assert that it is even more important to have a proper relative humidity in the school room than to have a proper temperature.

Athletics should be encouraged for every boy and girl in school. In the past practically all of the attention was given to the few who were able to "make the team," while those who needed the benefits of athletics the most received none or very little. The athletic training should be of a kind that will build up strong and healthy bodies.

Child labor is rapidly becoming a thing of the past in the United States, because it is a poor national policy to retard the development of the minds and bodies of the growing generation. Compulsory education in some form should continue until the age of eighteen is reached.

The City.—It is the duty of every city to supply its children with playgrounds properly equipped. The need is not so great in small towns where there is plenty of room for the children to play, but it is an absolute necessity in large cities. Has your city a skating pond large enough to accommodate all of its children? Has it an improved, free bathing beach? A stream or pond should be made available, and should be supervised, no matter how small the town may be. What can you do to help get a skating pond and a bathing place for the improvement of the health and life of the young people of your community?

The United States government has good laws protecting its citizens against adulterated foods, but these laws can not be effective

unless the citizens are willing to aid in their enforcement. Are they properly enforced in your community? Are the herds from which your milk comes properly inspected for tuberculosis, and are the stalls kept clean? Do you know where your milk comes from? Give a report in class on the dangers of impure milk.

Are there any flies in your grocery store and meat market? What are some of the things that boys and girls can do to keep the places where food is sold free from dirt and germs? Borrow from the International Harvester Co. of Chicago, Ill. their free set of lantern slides (or charts) on the house fly. If it is now early spring study No. 66 may be taken up at this time out of its regular order.

Contagious Diseases.—Ex-President Roosevelt said in a message to congress, "There are about 3,000,000 people seriously ill in the United States, of whom 500,000 are consumptives. More than half of this illness is preventable. If we count the value of each life lost at only $1700 and reckon the average earning lost by illness at $700 a year for grown men, we find that the economic gain from mitigation of preventable disease in the United States would exceed $1,500,000,000 a year." Who are the members of the board of public health of your city? Who is the health officer? Are the quarantine laws rigidly enforced? Discuss in class why you should be concerned about this matter. It is a disgrace to any city now to have an outbreak of typhoid fever, smallpox, or yellow fever. They are all caused by germs and can be prevented.

Suggestion.—It is not to be expected that very many of the students will be familiar with the problems raised in this study. They may be brought before the class in the form of reports by volunteers from the membership of the class.

Can it be arranged to have the city forester or other officials speak to the class on civic problems in which they are interested?

UNIT VI. THE DOCTRINE OF EVOLUTION

53. PLANTS AND ANIMALS OF THE PAST

What do we know about the ancient life of the earth?

The ancient life of the earth was much different from what it is to-day. There was a time when man did not exist, and there was a time when no birds or mammals inhabited the earth. Still earlier there was a time when there were no reptiles or amphibians, and in very ancient times there were no fishes. The group of vertebrate animals was the last of the great groups to appear. In general the simpler forms came into existence first, and the more complex ones later. In the plant kingdom the algæ came first, then the mosses and liverworts, then the ferns and their allies, and lastly the flowering plants.

The changes in plant and animal life on the earth have been very slow, and the length of time during which the earth has been inhabited is very great. Just how great can not be determined until more information about the past has been obtained. Some authorities have estimated that the first fossils of animals were deposited in the mud of the sea bottom 100,000,000 years ago, and life probably existed a very long time before it left any trace of itself in the rocks which were forming under water.

Our knowledge of the past is obtained by studying the remains of animals and plants which are imbedded in stratified rock. As the land was worn away the sediment was carried to the sea as it is to-day. A very few of the total number of creatures which died were buried in this sediment at the bottom of the water, and when it finally became rock the likeness of the plants and animals was preserved.

The law of superposition is that the more recently formed layers of rock rest upon those that were formed earlier. Why must this be so?

The law of included organisms is that the animals and plants found in a stratum represent the types which lived when that layer was formed. If a layer of shale in Europe and a layer of limestone in America contain the same fossils, it is assumed that the two strata were formed at the same time.

Geologic time is divided into five *eras*, the last three of which are again divided into ten *periods*, and these are divided into *epochs*. The terms *group*, *system*, and *series* are used to designate the rocks which were formed during the eras, periods, and epochs respectively. This classification is shown in the following table.

ERA AND GROUP	PERIOD AND SYSTEM	EPOCH AND SERIES
CENOZOIC	Quaternary (man)	Recent Pleistocene
	Tertiary (mammals)	Pliocene Miocene Eocene
MESOZOIC	Cretaceous Jurassic Triassic (reptiles)	
PALEOZOIC	Carboniferous (ferns) Devonian (fish) Silurian Ordovician Cambrian (invertebrates)	
ARCHEAN	(no fossils)	

The rocks of the **archean** era contain practically no fossils, but do contain beds of limestone, iron ore, and graphite which suggest that life existed while they were being formed but was of too delicate a nature to be preserved

The **paleozoic** era began with the Cambrian period the rocks of which show evidences of the existence of all of the invertebrate *animal phyla,* but no plants. It is believed, however, that plants *existed before animals,* because they furnish the food of the animal

kingdom. They were probably as yet too soft to be preserved. More than 500 different species of animals have been found in Cambrian rocks; of these the class of Arthropods, known as *trilobites*, were the dominant type of animal life of the period. In spite of the fact that there were hundreds of species of them during the Paleozoic era, there are none at all to-day, and there is no evidence of their existance after the close of the Carboniferous period.

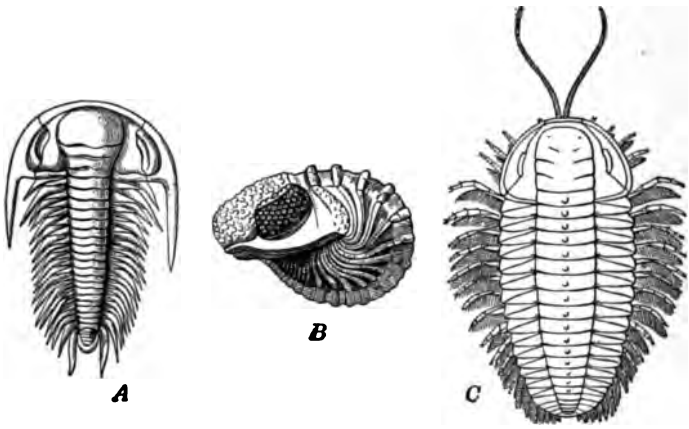

FIG. 278.—Three trilobites. *A*, a Cambrian species; *B*, a Devonian species, showing a compound eye (Note that the abdomen is folded under the thorax); *C*, an Ordovician species. (*Norton, Elements of Geology.*)

The plant life of the Carboniferous was luxuriant and is described by Norton in *Elements of Geology* as follows:

"The gloomy forests and dense undergrowths of the Carboniferous jungles would appear unfamiliar to us could we see them as they grew, and even a botanist would find many of their forms perplexing and hard to classify. None of our modern trees would meet the eye. Plants with conspicuous flowers of fragrance and beauty were yet to come. Even mosses and grasses were still absent.

The ferns lifted their crowns of feathery fronds high in air on trunks of woody tissue; and lowly herbaceous ferns, some belonging

FIG. 279.—A Carboniferous landscape.

to existing families, carpeted the ground. Many of the fernlike forms, however, have distinct affinities with the cycads, of which they may be the ancestors, and some bear seeds and must be classed as gymnosperms."

The **carboniferous** animal life is characterized by an abundance of amphibians. Fishes dominated the life of the previous period, and toward the close of the Carboniferous period, during the Permian epoch, the reptiles made their appearance and became the dominant type of life in the Mesozoic era. Although both animals and birds made their appearance in the Mesozoic era they did not become abundant until the Cenozoic.

The ancestry of the horse has been as completely worked out as that of any existing mammal. In the Eocene epoch the horse was five-toed and about the size of a cat. By the end of this epoch it was three-toed and as large as a sheep. In the Pliocene it walked on its middle toe, and the toes corresponding to the first and third fingers were reduced to splint bones as they now are. The ones corresponding to the thumb and little finger had disappeared entirely. Although the complete history has been made out from fossils found in North America, the horse did not inhabit this continent when it was discovered. Asia and North America were at one time united, and the pig, horse, camel, carnivores, and elephants of those days crossed back and forth freely. None of these forms were found in Australia, however, because it was cut off from the other large land masses before the higher mammals came into

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FIG. 279.—Restoration of a scene along a sluggish creek in Texas and New Mexico during the late Carboniferous (Upper Pennsylvania) and early Permian times. The lowlands of this period doubtless swarmed with reptiles such as are shown in the picture, and with other animals, now extinct. Some specimens of the giant "dragon-flies" had a spread of wings of two feet. The fern-like trees and the bushy plants in the foreground are Cycadofilicales. To the right of the water are wide stretches of the huge scouring rush (*Calamites*); on the left bank of the stream are the unbranched *Sigillarias* (still as prominent as earlier in the coal period), and on higher ground to the left the branched *Lepidodendrons*. One must view this scene as one of many such landscapes, with evervarying detail, along streams and inlets. *Cordaites*, which in later Devonian time made the first great forests of which there is record, is still present, though not shown. So, too, there are hidden in the recesses of the forest the forerunners of the modern coniferous types, as well as other forms destined to give rise to the angiosperms. (*Landscape from Williston, adapted from* Neumayr, legend from Gager.)

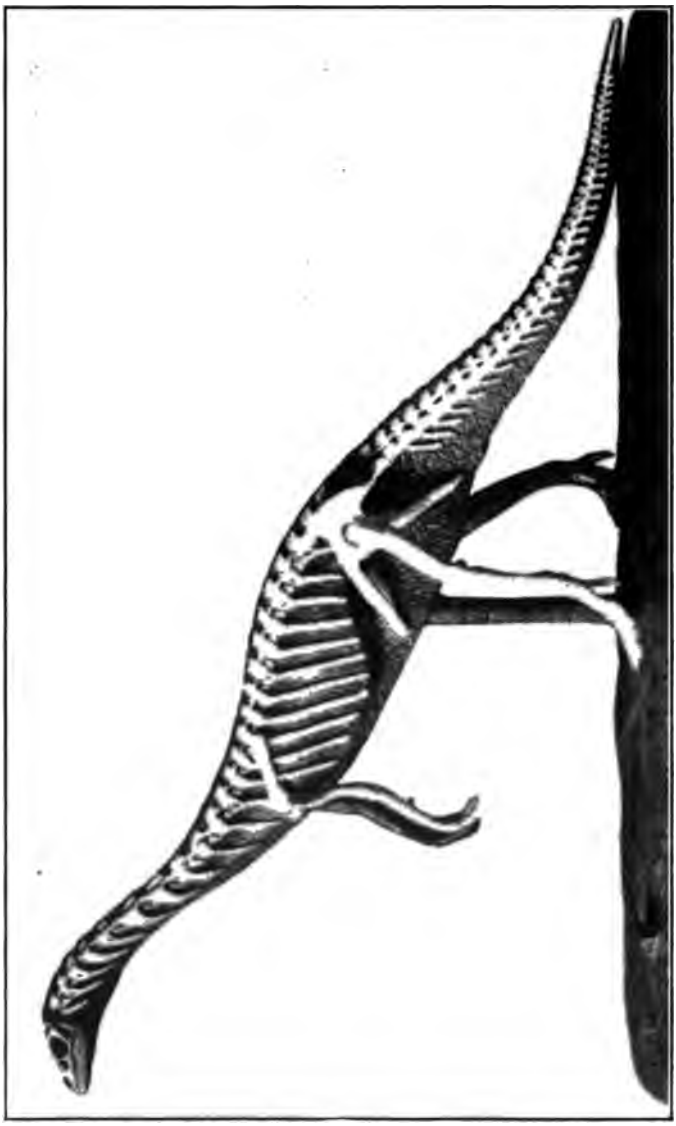

FIG. 280.—An ancient reptile from the Triassic period, found in Connecticut. (*After R. S. Lull.*)

existence; and the camel, horse, and elephant perished in North America after it was cut off from Asia. For a complete history of the evolution of the horse see *Origin and History of the Horse*, by H. F. Osborn.

The Origin of Man.—Many interesting fossils of primitive man have been found. A very important one was found in 1881 in early Quaternary or late Pliocene strata. It consisted of a skull and leg-

FIG. 281.—One of the three toed ancestors of the horse. This creature lived in the western part of the United States and was about the size of a dog. (*Painted by Chas. R. Knight under the direction of Henry Fairfield Sanborn, American Museum of Natural History.*)

bone of a creature which walked erect like a man but in many other respects resembled an ape. This creature has been called *Pithecanthropus erectus*, and is believed to represent an ancestral type of man. Man is not believed to have inhabited North America before the Glacial epoch.

Project.—Begin making a collection of fossils for the museum. They are more numerous than most people think. Most any gravel bed will supply several kinds.

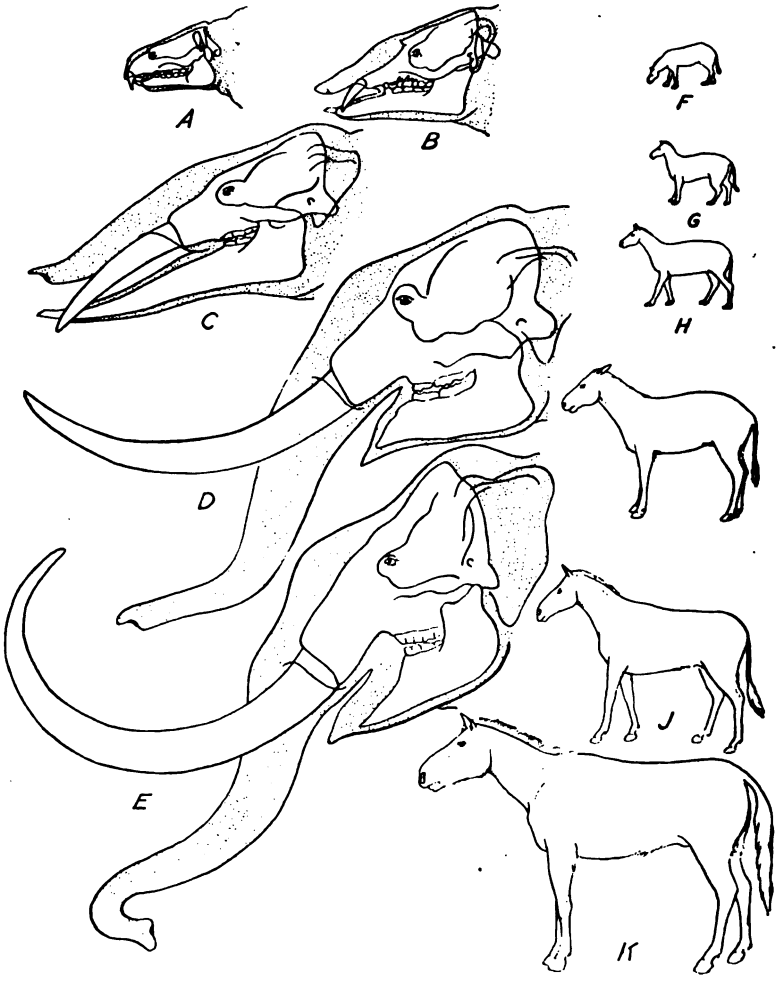

FIG. 282.—Diagrams showing the evolution of the elephant and horse. The drawings are based upon fossils dating back to the Eocene Epoch. (*From Pearse, General Zoology, after Lull.*)

54. THE PROOFS OF EVOLUTION

What evidence is there that the present life of the earth has descended from the life of the past?

Spontaneous Generation.—For a long time people believed that life arose spontaneously,—*i.e.*, without cause, from the mud of ponds or from decaying matter. The early interpretation of fossils was that they were rock which was taking on the form of animals, and would some day come into life. It is now believed that *life comes only from life*, and by no other way. The origin of the first living things from which all other living things have descended is still a mystery, but some day it will be known.

FIG. 283.—Photograph of a restoration of the skull of man compared with that of *Pithecanthropus*. How do they differ?

Descent.—Having disposed of spontaneous generation, there remains but one explanation for what Darwin called the "mystery of mysteries,"—the diversity of the species of plants and animals. It is that in some manner life came into being on the earth in the form of a single cell and has diverged from this parent form to produce all of the types which we now have, each species having descended from a preceding species. According to this view species are constantly changing with the changes which take place in environment. So much evidence has been gathered in support of this explanation that it is considered a biological law and is known as

evolution or *descent*. Of the two terms perhaps "descent" is the better because it more accurately expresses the idea, but "evolution" is the more common.

The PROOFS FOR THE LAW OF DESCENT are gathered from six fields of scientific research. They are *paleontology*, *comparative anatomy* or *morphology*, *embryology*, *animal behavior*, *geographical distribution*, and *experimentation*.

FIG. 284.—Hand and foot of the Chimpanzee. Note their similarity to those of man. (*From Home and Country Magazine.*)

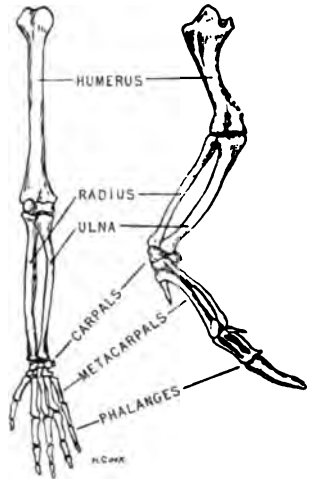

FIG. 285.—The bones of the arm of man and of the wing of a bird. What ones are lacking in the wing?

Paleontology means the science of ancient things, and was discussed in the previous study. From a study of fossils we learn that (1) *the life of the earth has changed slowly throughout the ages.* We also learn that (2) *the simple things came into being first* and that (3) *the ancestral forms have perished from age to age and have been replaced by more highly specialized species.* Lastly, (4) *no evidence has been produced from paleontology which is contrary to the law of descent.* If there was no other evidence would you feel justified in founding a theory on the above mentioned four facts? There is *no absolute proof* in paleontology that the new forms *descended*

from the old, but it does prove that they *succeeded* them. We must go elsewhere for the proof of parentage.

Comparative Anatomy.—The evidence which is to be gained by a comparative study of the structure of animals and plants is that

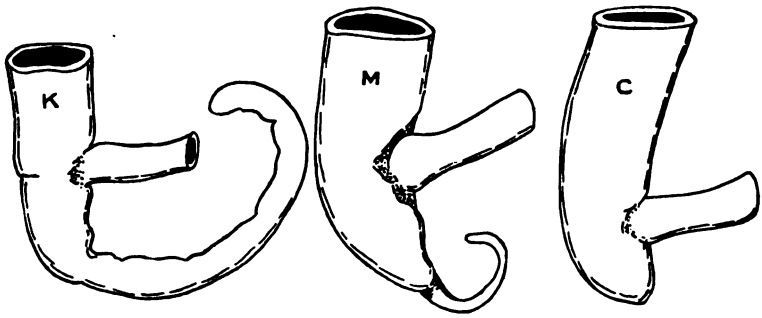

FIG. 286.—Diagram of the appendix in—*K*, the kangaroo; *M*, man; and *C*, the cat. The kangaroo is the most primitive, having an appendix which functions in digestion; man is intermediate, having an appendix which does not function; and the cat has none.

those forms which are closely related are built on the same plan, and the closer the relationship the closer is the resemblance. All of the animals in the same phylum have a general resemblance to each other, those in the same class or order are still more alike, and those in the

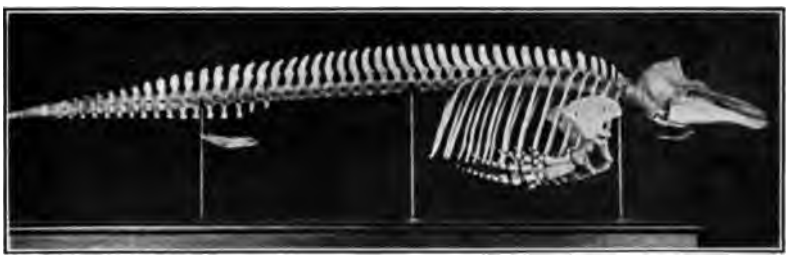

FIG. 287.—Photograph of the skeleton of the porpoise, showing the remains of the bones of the hind limbs.

same genus or species are very much alike. The bones in the arm and hand of man are the same as those in the monkeys, the only differences being those of shape and size. In the other mam-

mals the same bones appear, but with greater modifications. In the horse, as we have noted, some of the hand and finger bones have been lost. In the bird's wing the same bones appear also, but those of the hand and wrist have been both fused together and reduced in number.

The second fact from comparative anatomy is that of *vestigial structures*. These are structures,—such as the appendix in man and the bones of the hip girdle in the whale and porpoise. In these two fish-like mammals the hind legs have disappeared. The presence of these useless structures can be explained in only one way—they have been inherited from ancestors which possessed them in a perfect form and used them.

The third fact from comparative anatomy is that *we do not find structures where we do not expect them*. For instance, fish do not have legs and arms, and mammals do not have fins.

Embryology.—From a study of embryology we learn that *every animal and plant in its life history retraces in a general way the structural history of its ancestors*. For example, each animal begins life as an egg which corresponds to the first single celled life of the earth. In the studies on the life histories of the frog, bird, and mammal (39, 40, 41) it was shown that each form has gill-slits in its embryonic life, but not in the adult. This fact is known as the *law of recapitulation* and is perhaps the most significant of all of the proofs of descent. The presence of gill-slits in the embryo of man, for instance, can be accounted for on no other basis than that our remote ancestors were at one time fish-like and lived in the water.

Animal behavior is the study of the psychology of animals. It has become a popular field of biological research in recent years. Even the most complex mental characteristics of man are foreshadowed among the lower animals. The indications are that we may conclude that there has been, not only a physical evolution, but that mentality also has evolved from the lower groups. We may be more positive about this conclusion when more research has taken place.

Geographical Distribution.—The most important proof of descent to be had from a study of the geographical distribution of plants and *animals is the fact of adaptation*. The fox of Virginia, the European

fox, the kit foxes of Canada, the Alaska foxes, and the arctic fox all differ from each other; yet they are all foxes; and each is peculiarly adapted to live in the territory where it is found. For example, the arctic fox turns white in winter, and prepares a cache of frozen game on which to live during the long winter.

The phenomena of adaptation are too universal and perfect to accidental. There is a causal relation between the environment be and the structure and habits of animals. We are forced to conclude either that environment has been made to fit life (the old view), or that life has been fitted to environment (the modern view). A brief discussion of adaptation was given in Study 3.

FIG. 288.—Photograph of the red and grey foxes of North America. The two in the foreground are grey foxes in their summer coats. The other is a red fox in winter coat.

Experimentation.—The scientist is not satisfied with a theory or law until he can test it out by experiment. The experiments to prove evolution are mostly in the field of plant and animal breeding about which something has been said in previous studies. The most important fact contributed by experimentation is that *species can be changed.* In order to realize the full significance of this one need but recall the many varieties of dogs,—all derived from the wolf and his relatives; or of the many varieties of chickens, or of wheat, or most any other domesticated animal or plant.

The mass of evidence which we have outlined constitutes so complete a case that all well read biologists accept the doctrine of evolution as the explanation of how the life of the earth came to exist.

in its present form. In the next study we shall try to see how this process of creation took place, and what were the forces at work which brought it about.

55. THE METHOD OF EVOLUTION

How do species change?

Descent was accepted by the best biologists as the explanation of the origin of the diverse species of living things before the time of Darwin, but scientists had not as yet been able to explain how it took place; and the scientist does not readily accept a new theory until its causes have been investigated and are understood.

LAMARCKIANISM is the name of one of the first explanations of evolution. It was quite clearly set forth by Lamarck, a French biologist, in 1802. It was based upon the belief that the environment is able to directly affect the plant or animal (which is to a considerable extent true) and that these affects are passed on to the next generation. It is often spoken of as the *inheritance of acquired characters*, and has been referred to before (Study 51). The German biologist, Weismann, attacked this theory and showed by experiments that it can not be accepted as the method of evolution for variations which are caused by the direct action of environment, exercise, or desire are not passed on to the next generation. Weismann's conclusions were generally accepted in the beginning of the present century and a hundred years of dispute on the transmission of acquired characters seems to be laid aside forever.

FIG. 289.—Jean Baptiste Lamarck (1744–1829). (*From Gager.*)

ORTHOGENESIS is the name of a theory devised by a school of vitalists (see p. 124) who believe that there is some inherent, unknown force within life which compels it to diverge along definite, predetermined lines. The evidence which has been brought forth in support of this theory is at present insufficient.

NATURAL SELECTION is the name of the theory which was set forth by Darwin. It is based on the two unquestioned facts of *variation* and *heredity* which it need not attempt to explain, and on three conditions which constitute *the formula of natural selection.*

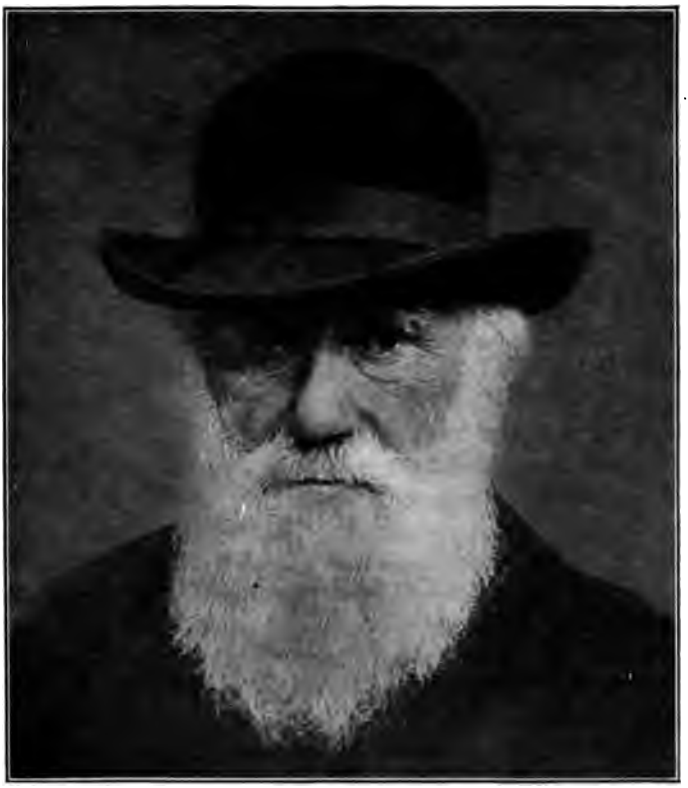

FIG. 290.—Charles Darwin, the author of *Origin of Species.* (*From Gager.*)

They are *overproduction, struggle for existence,* and *survival of the fittest.* Some comment on these terms is necessary.

I. Overproduction.—The female codfish lays from two to eight million eggs per year. If they should all hatch and reach maturity, and continue to reproduce at that rate, "the ocean would soon be so

full of fish that there would be no room for the water!" Obviously, they can not all survive. Actually, there is, on the average, only one pair produced to replace each pair which dies. This means that millions must die of under-nourishment or fall a prey to their enemies.

If you measure off a square yard of ground and count all of the plants which come up there in the spring, there will probably be from ten to one hundred times as many as can grow to maturity. All life would overproduce itself in a very short time if it were free to multiply to an unlimited extent. Even the elephant which does not produce more than one calf in three years would overrun the earth in one century if it were not restrained.

II. Struggle for Existence.—Among the abundant offspring of any species there is a contest or struggle to live and to reproduce the species. This contest may be for room, for food, against enemies or the forces of nature, or among individuals of the same species. Among plants it is a passive struggle; but it is, nevertheless, very intense. One needs but to go into the woods and note the dead branches, killed by shading, or the tall saplings, or the abundant shade plants to realize how rigorous this struggle is.

III. Survival of the Fittest.—According to Darwin's theory the animals and plants which are the best fitted to live (by the law of variation they will not all be equally fit) will have the best chance to survive in this struggle. Therefore, *overproduction* produces or intensifies the *struggle for existence*, and the struggle for existence results in the *survival of the fittest*.

Heredity.—It is here that heredity is called upon. The fortunate variations must be preserved by heredity if the next generation is to be different from and better fitted to the environment than the one which went before. Thus nature unconsciously and mercilessly selects the fittest to reproduce the race, and slowly, very slowly, changes the life of the earth as the environment changes. If environment stood still there would be little evolution. Do you clearly understand that while a changing environment is the causal factor which produces evolution its action is not direct, but indirect? Environment does not produce change or variation; it eliminates unfortunate variations and preserves the forunate. It is just here *that the theories of* Darwin and Lamarck differ, and of all technicali-

ties in biology, this is the most difficult for the average student to perceive.

DARWINISM.—The theory outlined above which Darwin himself called *natural selection* is often called *Darwinism*. When the term is used it is not a synonym for evolution, as is commonly understood, but applies only to the theories of selection which Darwin announced. Natural selection is the only acceptable explanation of the question, "How did evolution take place?" It will be modified as to detail from time to time, but its essential principles will stand. Among these modifications are the supporting theories of *artificial selection*, *sexual selection*, *isolation*, and *mutation*. They have been designed to cover cases which can not be explained by natural selection alone, and were fully set forth by Darwin, and admitted as necessary.

Artificial selection is selection by man instead of by nature. Man selects animals, not so much for their fitness to live in a natural environment as he does for their asthetic or economic value to him. The fat hog, dairy cow, seedless orange, and yellow dent corn could not survive if they wer turned back to nature and left unprotected by man.

Sexual selection theories have been designed to explain such structures as the tail of the male peacock, the antlers of the stag, the enlarged antennæ of the male mosquito, the drumming of the partridge, and the gallantry of the barnyard cock. These characters are of assistance in mating, and the theory states that those animals which possess the best characters of this kind are the most apt to leave offspring, and perpetuate their superiority.

Isolation accounts, in part at least, for the differences existing between the fauna and flora of continents and their outlying islands; or between the red fox, for instance, of Europe and of North America. If a barrier which can not be crossed by a species divides its territory it may become different on opposite sides of the barrier owing to differences in the environment and an inability to interbreed with the isolated portion of the species. Name some animals and plants which would find it difficult to cross the following barriers: salt water, fresh water, deserts, tropical climate, arctic climate, mountain ranges prairies, forests.

Mutations are cases of discontinuous variations. They were

discussed in the study on "Variations." Interest in mutation as a supporting theory has been revived recently as a result of the work of de Vries, a Dutch botanist, who thinks they are of greater importance than any other factor; but they probably play a small part in nature. Their tendency to breed true to type has made them of great value in plant and animal breeding.

Debate.—It will be found to be interesting and profitable to appoint teams and devote one or two class periods to a debate on some phase of evolution.

Review.—The subject matter of the studies on variation and heredity should be clearly in mind in order to appreciate their relation to the subject of evolution.

UNIT VII. A FEW PROBLEMS IN CIVIC AND ECONOMIC BIOLOGY

56. FUNGUS PLANTS

What is the relation of fungus plants to man?

The fungus plants which have been named number 66,700 species. This is over one-fourth of all known species of plants. They are devoid of roots, stems, or leaves and resemble the algæ in many details, having, in all probability, descended from them. They differ from the algæ in that their spore bearing structures in the highest forms are more complex, and in that they have no chlorophyll. The absence of chlorophyll is their most distinguishing characteristic. It causes them to be dependent upon food-stuffs which have been prepared by the green plants and animals. They, therefore, play the same general role in nature's food-cycle which is played by the animal kingdom. Because of this dependence they are compelled to live either as *parasites* (living on living things), or *saprophytes* (living on dead things), or in some cases they are either saprophytic or parasitic in which case they are said to be *facultative.*

The economic importance of this group is realized when we say that there would be no decay, no humus soil formation, no fermentation, and few contagious diseases if it were not for the fungus plants.

In this study it will be necessary to confine our attention to three types of fungi. Others will be studied in following lessons.

Bacteria.—For our purposes this division may be classified according to their shape into three groups, which are the *coccus* group which is composed of spherical forms, the *bacillus* group which comprises the rod-shaped species, and the *spirillum* group composed of spiral-shaped bacteria. (See Fig. 299.)

Reproduction.—In their methods of reproduction bacteria are like the blue-green algæ. Each individual is a single cell and on attaining full size, divides through the center and becomes two

individuals. For this reason they are called the *Schizomycetes* (Gr. *schizo* = to split + *myces* = fungus). Many forms of bacteria produce resting spores to tide them over an unfavorable period of drought or other condition not conducive to their welfare. When in the spore condition they can withstand great extremes

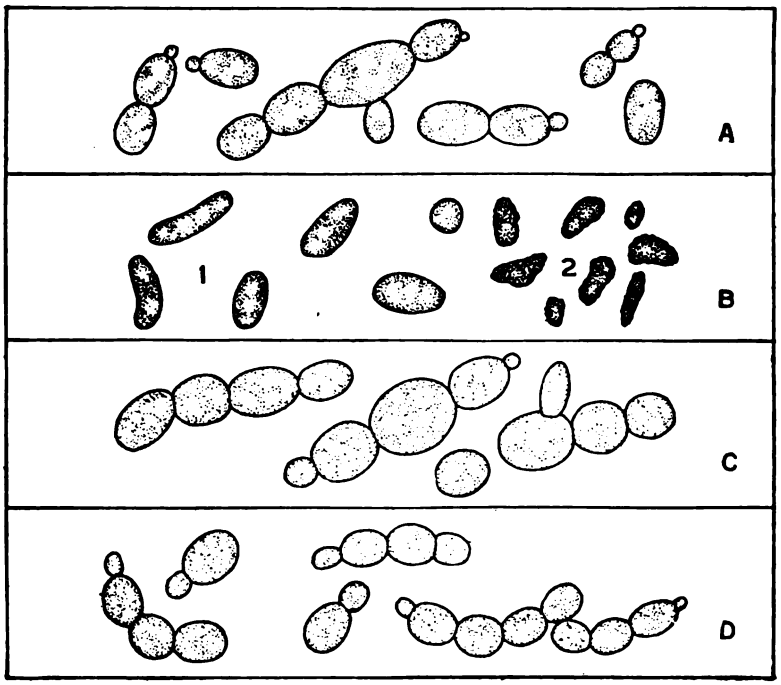

FIG. 291.—Yeast cells, showing their method of reproduction by budding (*A*). *B*, 1. old cells; 2, dead cells; *C*, bottom yeast; *D*, cells from top. (*Marshall.*)

of dryness, heat, and cold. Fortunately, few of the forms causing human diseases produce spores, and, hence, they are easily killed.

Bacteria are everywhere. We eat them, drink them, and breathe them in countless millions; yet they ordinarily do us no harm. Milk, buttermilk, cheese, and sauerkraut swarm with them. They are present on the surface of most all of our foods and cause decay if

the moisture and temperature conditions are suited to their growth. All spoilage of food is due to bacteria and other fungi.

Yeasts are fungi of uncertain ancestry. They multiply by budding, as shown in the illustration. They are much larger than bacteria and have a large, clear nucleus. At certain times they

FIG. 292.—The smooth lepiota (*Lepiota naucinoides*). The cap, ring, and stem are well shown. This species is edible, but because of its resemblance to the amanitas it should be avoided. Note that it has a bulb but no cup.

form spores in groups of two, three, or four. They live principally in sugar solutions, and are, therefore, called *Saccharomycetes* (Gr. *saccharon* = sugar + *myces* = fungus). They change sugar into alcohol and carbon dioxide according to the following formula:—

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{alcohol}}{2C_2H_6O} + \underset{\text{carbon dioxide}}{2CO_2}$$

In bread making the carbon dioxide which is produced by the yeast fills the dough with many small spaces. When it is baked the alcohol formed is driven off, the yeast is killed, and the dough hardens leaving the bread spongy.

In spite of the great benefit derived from yeasts in bread making, they have been one of the greatest curses of mankind. Nearly every people has had its intoxicating drink made by the action of yeasts on grain or fruit juices. Now that the traffic in alcohol has been abolished in the United States the yeasts may be counted as

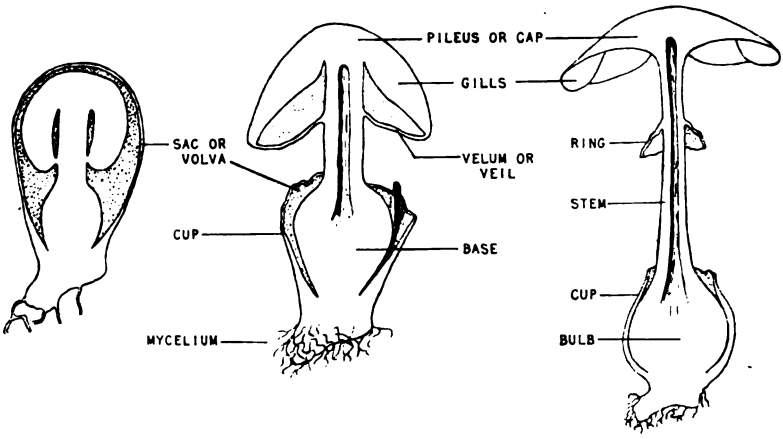

FIG. 293.—Diagram of the death cup (*Amanita phalloides*) to show its characteristics by which it may be known.

almost wholly beneficial to man. When the supply of petroleum is exhausted we may run our automobiles by alcohol derived from the action of yeast on wood pulp, corn stalks, and the like.

Mushrooms abound in fields and woods from spring to winter, but they are most abundant in the fall. They are multiplied by spores which are easily scattered by the wind. For this reason the same species are usually found on all of the continents. Most localities should yield about 1,000 varieties. *Nine of these are deadly poisonous*, all of which belong to the genus *Amanita*. McIlvane lists 735 which are edible. Fortunately it is possible to identify

the amanitas by their *white spores, the presence of a ring*, and *a cup or swelling at the base.* Furthermore, the amanitas usually grow in the woods. *Beware of mushrooms with white spores.* All others are probably good if they are palatable.

Mushrooms contain a great amount of water but are very rich in protein food, and are a better food than meat because they are more easily digested; but because of an inability on the part of the public to distinguish the amanitas, and, hence, a fear of all forms; tons of this most excellent food go to waste in every locality each year. On your field trips learn to know the poisonous ones, and gather the others.

The mushroom is the fruiting structure of the plant and is called the *sporophore* (spore bearer). In the soil many thread-like filaments may be found. They are the vegetative body of the plant and are called the *mycelium.* A single thread is called a *hypha.* When a sporophore is young it is rounded in form and is called a *button.* It is entirely enclosed in a membrane called the *volva* or *sac.* As the button grows it is pushed upward by the lengthening of its stem, and the volva is ruptured. The part remaining about the base of the stem is called the *cup.* The sporophore is composed of a *stem*, a *pileus* or *cap*, and *gills* or some other structures which bear the spores. *Warts* are patches of the volva remaining on the upper surface of the cap. The *velum* or *veil* is a membrane which attaches the edge of the cap to the stem and is ruptured when it expands. In the amanitas it leaves a *ring* around the stem. All mushrooms do not contain all of the structures mentioned, but a knowledge of the above terms is necessary in identifying and classifying fungi.

Do not let the wild mushrooms go to waste in your community. Have a report given on the raising of domestic mushrooms for market. Write to the Department of Agriculture, Washington, D. C. for a bulletin giving complete information on this profitable industry.

Not all mushrooms, by any means, are beneficial. Some live on the trunks of trees, and finally destroy them. Such trees show *brackets* or *shelves* on their bark. (See Fig. 102.) If diseased trees are not removed the spores produced in the brackets will affect

other trees which may have a wound due to a broken limb or an insect injury through which the spores may gain lodgment. What can you do to prolong the life of the trees of your city?

All diseased trees should be cut down and removed at once. It is usually useless to try to save them by tree surgery. Make

FIG. 294.—The shaggy-mane mushroom (*Coprinus comatus*), the finest and most beautiful of the wild mushrooms. When ripe it turns black and melts away to an inky fluid filled with black spores. All mushrooms which do this are called "ink caps." They are all edible when young.

a census of your block in the city. How many trees should be removed? Can you do anything to better this condition?

Laboratory Work.—Make cultures of bacteria in gelatin or bullion media. Inoculate them with dust from various places. Let a fly walk across a dish of gelatin. Put the cultures in a warm place and note the growths which take place. Squash, potato, and apple are good culture media if kept moist after being inoculated.

57. THE PRESERVATION OF FOOD

How do yeasts, molds, and bacteria interfere with the preservation of food?

All food; whether it is meat, fish, grain, cereals, fruits, or vegetables, must be cared for by special methods to preserve it from the time it is prepared until it is consumed. Bacteria, yeasts, and the spores of molds are everywhere. The conditions favorable to their growth are the presence of food, warmth, and moisture. They are

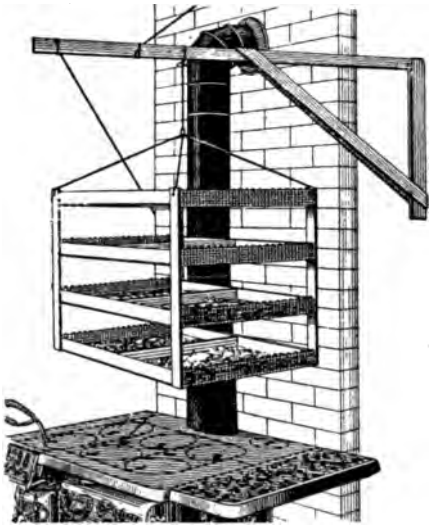

FIG. 295.—A home-made dryer to be hung over a stove. (*National War Garden Commission.*)

in no way dependent upon sunlight as are the green plants, and because of the great number and small size of their spores they penetrate to all places which are not hermetically sealed. Wherever conditions favor their growth they appear.

Drying.—Some of the methods of preserving food are as old as civilization. The ancient people dried their grain, and stored it in bins. The American Indian dried buffalo meat. This is one of the safest and simplest methods of preserving food from spoiling, for

bacteria can not grow where there is no moisture; and *unless the fungus plants grow in food it will keep forever.* They are the sole agents of decay.

In modern times meats and fish are dried and smoked. Apples, peaches, and Logan berries are evaporated in special ovens made for the purpose. Prunes and raisins are dried in the sun.

If hay is not thoroughly dried before it is put in the haymow the bacteria living in it may generate enough heat to start spontaneous combustion which may set it on fire. Make a list of the food materials which are preserved by drying, and have some reports given on various special methods which are used.

Salting is another simple and ancient method of preserving food. Bacteria can not live in strong salt solution, nor can they live in meat that is partially dried and thoroughly salted. Salting is still extensively used for preserving fish and meat. Beans and pickles may be canned by placing them in strong brine. Sauerkraut is made by placing salt on cabbage, but not enough to prevent fermentation. The acid formed by the fermentation together with the salt finally stops the bacterial action, and the product is ready for use.

Acid stops or prevents bacterial action if it is strong enough. Some acids, such as benzoic and salicylic are very fatal to fungi but may be eaten by man and animals in considerable quantities. However, their use should not be encouraged as they are at least slightly harmful to some people. They do not affect everyone exactly alike.

Vinegar is made by allowing fruit juice or glucose to ferment. The sugar changes to alcohol under the action of yeast, and finally by taking on more oxygen and loosing water it changes to acetic acid.

$$\underset{\text{alcohol}}{C_2H_6O} + \underset{\text{oxygen}}{O_2} \rightarrow \underset{\text{acetic acid}}{C_2H_4O_2} + \underset{\text{water}}{H_2O}$$

The change to vinegar is accomplished by a fungus called *mother of vinegar* (*Micoderma aceti*). It may be found as a felt-like mat in the bottom of the vinegar jug. Examine it under the microscope. *When fermentation* has progressed to a certain stage no more action

takes place because of the acidity of the liquid. Vinegar is used in preserving sauces, pickles, beets, and spiced fruits.

Rhubarb contains so much acid that if it is cut up, packed in a can, covered with water, and sealed, it will keep without cooking. Ensilage is preserved by the acid which forms when the sugar in the corn stalk ferments. Material which contains no sugar will not keep in a silo. Why must clover, alfalfa, and soy beans be mixed with corn when they are put in a silo?

FIG. 296.—A steam pressure canner. (*National War Garden Commission.*)

Sugar in a concentrated form is a good preservative of food. Karo syrup, molasses, and maple syrup do not ferment if they are boiled to a viscous consistency. Fruits are often boiled in syrup and thus preserved; or dried fruits may be "sugared." Raisins, dates, and figs are examples. They contain enough sugar to preserve themselves when dry. Sugar and salt kill bacteria by extracting the water from them by osmosis. This explains why they must be in a concentrated form.

Sterilization consists in killing all bacteria and their spores which may be present in the material to be preserved or in the retainers in which it is put. It is usually done by heat. No bacteria can stand boiling for very long. If the work is done under steam pressure it is more thorough, and a shorter time is required to kill the spores. This is best done in an autoclave or some similar device. The cold pack method of canning fruit consists in putting fruit in jars cold, sealing them; then heating in boiling water or preferably in a pressure cooker until all bacteria are killed. In canning fruit or other material, if no bacteria or mold spores get into the can or under the cover, and if all that are present are killed by boiling, the fruit will keep forever. Sugar is not necessary in canning fruit, but if the work has been carelessly done the syrup may help to kill the bacteria which have not been destroyed, or those that may enter later.

FIG. 297.—A series of twelve pictures illustrating the single period cold-pack method of canning fruit. (*National War Garden Commission.*)

Pasteurization is a method of preserving milk. The process gets its name from the great French bacteriologist, Louis Pasteur. It consists in heating the milk to 170° F for from ten to thirty minutes. If the milk is heated more than this it will change chemically and taste like boiled milk. This temperature is sufficient to kill all disease producing bacteria. Milk so treated is not only safe, but it will keep longer. Why?

Refrigeration consists in preventing the growth of bacteria by cold. At temperatures around the freezing point of water fungi do not grow. If their growth is prevented, no matter how numerous they may be, the food will remain as it is. The flesh of the extinct mammoth of Alaska and Siberia has been found in ice perfectly preserved after being dead hundreds of years, and has been eaten by man and dogs.

Meats are frozen and packed for shipment on ocean liners which have refrigeration plants on board. All sorts of perishable food may be kept in cold storage plants where the temperature is just above the freezing point. The refrigerator and thermos bottle are valuable inventions with which we are all familiar. In the refrigerator the temperature is usually several degrees above freezing, and bacteria do grow there, but not so rapidly as they would in the warm air of the pantry.

Ptomaines are poisons which are the excretory products of certain bacteria which live in foods that contain much protein material. They cause serious intestinal trouble in man, and in some cases may cause death. Much of the indigestion which we suffer in the summer is caused by eating food which has partly spoiled and contains ptomaine poisons. Cooking may kill the bacteria, but it has no effect on the chemical composition of the poison. Hence, people are in as much danger from eating cooked food which contains ptomaines as they are in eating it raw. There is no good simple test which can be made to detect these poisons, and, for this reason, we should be all the more sure that we do not eat any food which has partly spoiled.

Suggestion.—Some practical work may be done in this subject by coöperating with the domestic science department.

58. THE CAUSE OF DISEASE

What is the relation of bacteria to disease?

Disease is a disorganized condition of the body which prevents it from functioning normally. Disease may be due to a variety of causes. We will study the tapeworm, the hookworm, and trichina as worms which cause disease in man. Malaria, yellow fever, sleeping sickness, and probably smallpox are due to protozoans. Tuberculosis, influenza, pneumonia, diphtheria, typhoid fever, whooping cough, bubonic plague, and hydrophobia are caused by

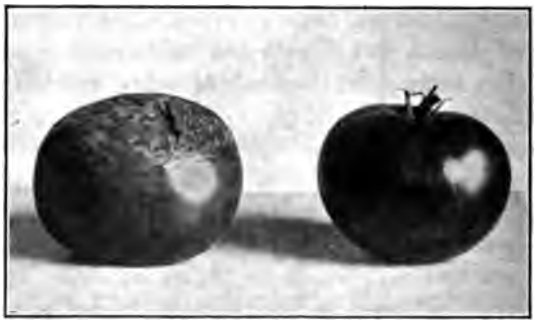

FIG. 298.—A scientific experiment to test the cause of disease. The tomato on the left was inoculated with bacteria (*Bacillus corolovorus*) from a decayed spot on a diseased tomato. The one on the right was not inoculated. Within four days the upper part of the inoculated fruit was destroyed. Repeat this experiment with other fruits. Are the conclusions that bacteria cause disease well founded? In these days of "faith cures" such experiments can not be too strongly stressed in schools.

bacteria. Asiatic cholera, relapsing fever, and syphilis are caused by spiral bacteria. Rheumatism, cancer, apoplexy, and goiter are not believed to be caused by microbes. Feeblemindedness, epilepsy, paralysis, and some forms of insanity are nervous diseases which are due to an inherited defective nervous system. Thus we see that the question of the cause of disease is a large one.

Malaria has been briefly discussed in study No. 25. (See Fig. 146.) It was formerly thought that it was due to vapors which rise from the surface of swamp water, because the disease occurred more abundantly near such places. Malaria is known to have affected man

since the earliest times; but not until 1880 was its cause known when Laveran, a French scientist living in Algiers, found the protozoön which causes it in the blood of malaria patients.

The last great biological discovery which marked the close of the nineteenth century was that malaria is carried by the female mosquito of certain genera and species of ANOPHELINÆ, (*Anopheles*

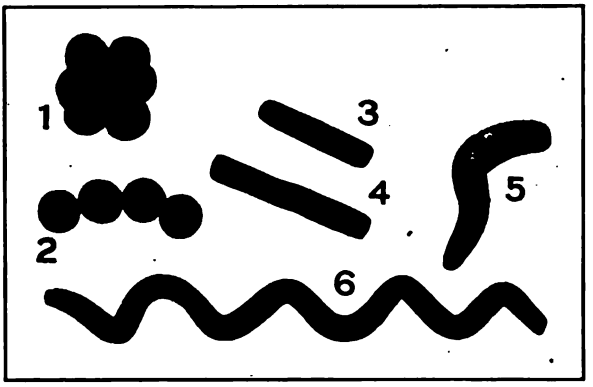

FIG. 299.—Types of bacteria which cause disease in man.

Coccus group	Bacillus group	Spirillum group
1, staphylococcus;	3, influenza;	5, cholera;
2, streptococcus;	4, tuberculosis;	6, syphilis.
Form pus and are associated with other forms in pneumonia.		

From a photograph of wax models, made by the author. Can the class prepare models of this type for all of the pathogenic bacteria? See illustrations in texts in bacteriology, and make the models to a convenient scale. Mount them in insect cases and save them.

punctipennis, etc.). Since the disease is carried only by this genus of mosquito, if we can prevent it from breeding there will be no malaria. This seems a simple matter, but the mosquito may breed anywhere where water stands for some time. Its young have been found in eaves gutters, tin cans, hollow trees, watering troughs, park fountains, rain barrels, and countless other places where water stands.

Another way to prevent the disease is to isolate all people who have it, and, thus, prevent the mosquitoes from becoming infested.

This is also very difficult for many people have it in a mild form and do not consult a physician. Still another way to prevent the disease is to avoid being bitten by mosquitoes, but this is also difficult to accomplish in practice.

Malaria can be cured by taking quinine at such a time that it will

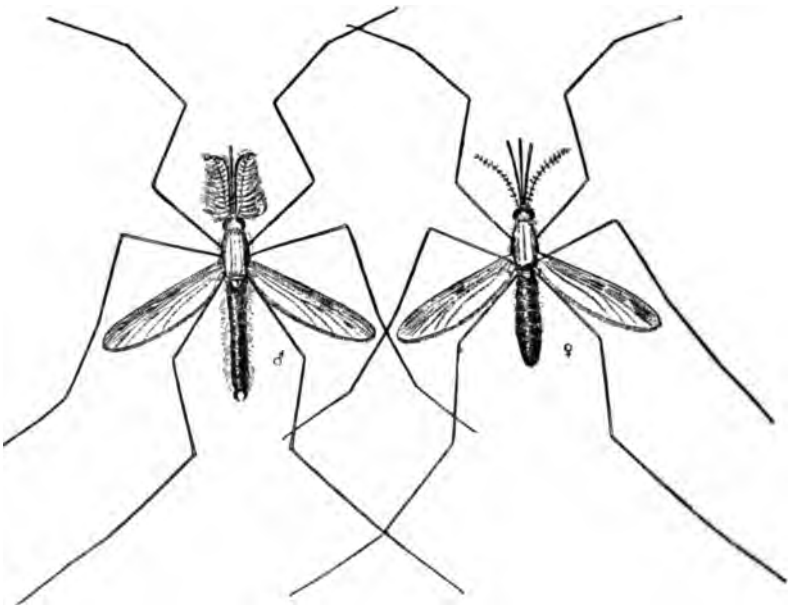

FIG. 300.—Male and female mosquitoes which cause malaria (*Anopheles quadrimaculatus*). Note the beautiful antennæ on the male. See study No. 20, and recall what they are used for. (*From U. S. Dept. of Agriculture.*)

be present in the blood when the microbes are released from the red blood corpuscles at the time when the fever occurs. (Fig. 146.)

All cases of malaria should be promptly treated and cured. The disease greatly weakens the system and lowers its resistance to other diseases. It very seldom happens that people die of malaria, but the losses in interruption in employment and reduced efficiency amount to millions of dollars in the United States annually, not to mention the physical suffering which it causes. Malaria can be

eliminated from our country by education and coöperation. Will you do your part?

Yellow fever is carried by a mosquito of the genus *Stegomyia.* The plague of yellow fever which was of frequent occurrence in our

FIG. 301.—A sleeping tent for tuberculosis patients, invented by Professor Irving Fisher, of Yale. The walls are movable so that protection from storms may be had or the sides may be open from any point of the compass. (*From the Michigan State Department of Health.*)

southern ports and Cuba has ceased to be, now that its cause is known and its prevention has been made possible.

Tuberculosis is the worst scourge of the human race. It causes more deaths than any other disease. In former years it was thought to be a constitutional disease and to be inherited because it "ran in families." In 1882 Koch, a German bacteriologist, discovered the

bacterium which causes it. He grew the microbes in a pure culture and inoculated guinea pigs with them, and produced the disease in the guinea pigs. This is the test which must be applied when a new disease producing bacterium is found. It must be present in the patient suffering from the disease, it must be raised in pure culture,

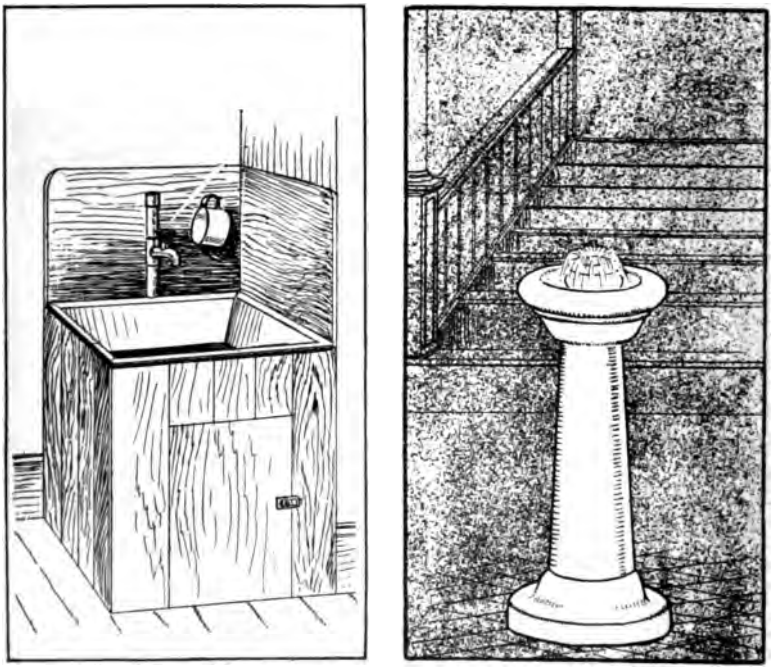

FIG. 302.—The old way and the new way, representing the progress made in one generation in the sanitation of supplying school children with water. (*From the Michigan State Department of Health.*)

and the disease must be produced by the bacteria when an animal or man is inoculated with them.

Tuberculosis has a tendency to run in certain families for at least two reasons—(1) If one member of the family has the disease other members are exposed to it and may take it. (2) Some families are by inheritance less able to resist certain diseases than other families

are. This point will be discussed under the heading "Immunit
in the next study.

No medicine is known which will cure tuberculosis because

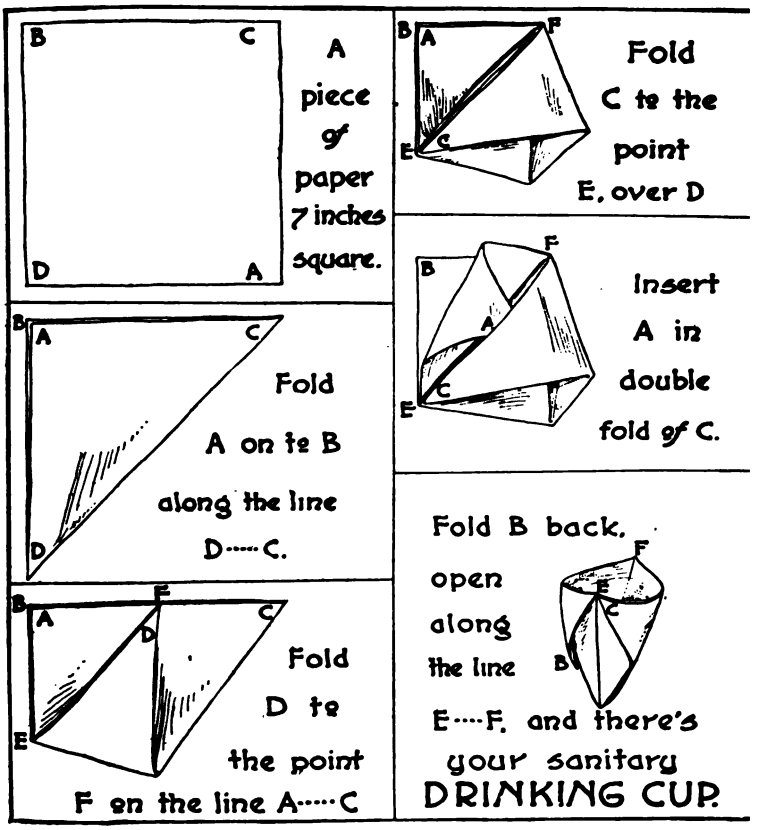

FIG. 303.—How to make a sanitary drinking cup. (*From the Michigan St Department of Health.*)

germicide has as yet been found which can be put into the lungs destroy the bacteria, and which will not have a bad affect on t patient. However, if the presence of the disease is known at an ea stage it need not prove fatal.

Tuberculosis can be cured by observing perfect rules of health. Fresh air, rest, and special food are the conditions upon which the cure chiefly depends. It is of the greatest importance that the presence of the disease be known before it has made much progress for

FIG. 304.—Four items in the formula for the cure of tuberculosis. (*From the New York State Department of Health.*)

after the body has become too much weakened it is usually too late to affect a cure.

***Prevention of* Tuberculosis.**—The sputum from persons who have *tuberculosis contains* tuberculosis bacteria. It should be collected

in cups and burned. No one, not even well persons, should be allowed to spit in public places. The germs may also be scattered by coughing and sneezing. There is some possibility that bovine tuberculosis, a tubercular disease in cattle, is caused by the same bacterium which infests man. Until we are certain that man can not contract tuberculosis from cattle we should exercise the greatest care in providing a milk supply from inspected, healthy cattle. *We should look upon any one who spreads tuberculosis as being guilty of murder. It is just as wicked to give your neighbor disease as it is to give him poison.*

Cancer is a very common and highly fatal disease. It will serve as an example of a disease which probably is not caused by microbes. It is most apt to occur between the ages of forty-five and sixty-five, and may affect most any part of the body. It is an abnormal growth of the cells of the organ which is affected. These cells become enlarged and continue to grow unchecked until they become inflamed, and finally the growth may spread to neighboring tissues and in the end cause death. Recent researches seem to show that cancer is not due to a microbe, is not contagious, and is not inherited. It is even doubted if a tendency to have cancer is inherited.

Cancer is believed to be caused by irritation which is prolonged. Neglected sores and ulcers, constant rubbing of the skin, continuous pressure, and unchecked inflammation are believed to be the chief causes of cancer. Any lump or persistent sore should be reported to a specialist at once, for if it is a cancer it can be removed if operated on while it is small. After it is easily recognizable as a cancer its removal may be impossible. *Cancer can be cured in but one way, and that is to cut it out.* Electrical, violet ray, and radium treatments are usually of but little value and should not be resorted to except in cases where an operation is impossible or inadvisable. No reliance whatever should be placed in any drug or poultice.

59. THE CONTROL OF DISEASE

How may the community be rid of bacterial diseases?

Immunity.—In the Previous study we mentioned the fact that some families are more susceptible to tuberculosis than others. *When an individual* is able to resist the attack of disease producing

bacteria and not have the disease which they produce, he is said to be *immune*. Immunity may be of two kinds,— *natural* and *acquired*.

Natural immunity occurs when an individual possesses an immunity which he has inherited. The white man is fairly resistant to influenza and tuberculosis because his ancestors have had these diseases for countless generations, and the families which have been resistant have survived and left offspring who were also resistant like themselves, and those who were not resistant have died of the disease whenever they have had it. In the winter of 1918–19 when the epidemic of influenza swept around the world, the population on some of the islands of the Pacific Ocean was almost completely wiped out. The American Indian and the Eskimo have a very low resistance to tuberculosis because the disease did not affect them until they came into contact with the white race.

In general a bacterial disease is confined to one species of plant or animal, and other species are said to be immune to it; but some diseases,—such as hydrophobia, tuberculosis, anthrax, and hoof and mouth disease may affect several species.

Acquired immunity may be acquired by an individual in four different ways—(1) by having the disease and recovering from it, (2) by vaccination, (3) by being injected with an antitoxic serum, and (4) by being injected with a toxin.

1. It is well known that people who have had measles, smallpox, whooping cough, diphtheria, mumps, and scarlet fever do not usually have the disease the second time. This ability to resist a second attack constitutes an acquired immunity. However, all diseases do not produce an immunity in those who recover from them. Pneumonia, influenza, and boils may be had an indefinite number of times. In these cases the immunity which is developed during the course of the disease, and which enables the patient to throw it off and get well, is not permanent. It is said to be *passive*.

Toxins.—The theoretical explanation of immunity is very simple. When disease producing bacteria live in the body they give off excretory products which are poisons much the same as yeast produces alcohol. These poisons are called *toxins*. If these toxins are produced in too great a quantity and are not thrown off or neutralized in the body, death will result.

Antitoxins are fluids which the body produces to counteract the toxins produced by the bacteria. If antitoxins are present in the blood in sufficient quantity the individual will not have the disease at all,—*i.e.*, he is *immune*. If he is able to produce antitoxin faster than the bacteria produce toxin he will recover, if not enough antitoxin is produced the bacteria will multiply and the case will result fatally.

Acquired immunity, then, is due to the fact that a sufficient amount of antitoxin is constantly maintained in the blood to prevent a recurrence of the disease. In some cases of passive immunity, such as influenza and pneumonia the antitoxin supply is not maintained in the blood for very long, and when it is gone the person is again susceptible.

2. **Vaccination** is resorted to to prevent smallpox. The individual is inoculated with a culture of smallpox germs which have been taken from a young heifer. The disease in cattle is either identical or similar to that of man, and is called cow-pox; but when the bacteria have been passed through the body of a heifer they are said to be *attenuated*,—*i.e.*, they are so weakened that they can not produce a severe disease in man. However, they can still cause a vigorous production of antitoxin to take place. This antitoxin remains in the blood for several years to render the patient immune.

Vaccination, then, consists in giving the patient a mild form of a disease in order to stimulate a sufficient production of antitoxin to ward off the disease which is vaccinated against. In all essentials the immunity produced by vaccination is the same as that produced when the patient has had the disease itself. Vaccination against smallpox has almost entirely stamped out the disease. In former years it was one of the worst scourges of the human race. Attenuated cultures of bacteria are also used to combat typhoid fever, hydrophobia, and hog cholera.

3. **Antidiphtheric serum** is an antitoxin which has been elaborated in the blood of the horse. Park, Davis and Co., Detroit describe its production as follows.

"Diphtheria bacilli are planted in beef bullion, where they multiply rapidly. Then they are killed by the application of a powerful germicide, and removed by filtration. The clear filtrate contains

the toxin, which is injected into the horse in small but gradually increasing doses. In time the animal acquires a tolerance or immunity to the toxin, antitoxin being developed in his blood. Then he is bled; and the blood-serum, separated and purified, constitutes *antidiphtheric serum.*"

It seems that the antitoxin which is produced in the horse is the same as that which is produced in the human body. Experience shows that after the serum is injected the progress of the disease stops. If it has not already done enough damage to cause death, the patient will recover. Hundreds of lives have been saved by its use, and diphtheria is no longer the dreaded disease which it once was. No child need ever die of diphtheria. If the diagnosis is properly made, and in time, recovery will follow the use of the antitoxin. All cases of sore throat which are accompanied by a fever should be reported to a specialist at once.

We have mentioned before that immunity may be permanent or passive. In treating diphtheria with the antidiphtheritic serum there is the degree of immunity which the body produces in fighting the disease, and there is the extra immunity given by the antitoxin from the horse. If the antitoxin is used and no case of diphtheria is present, the immunity due to the antitoxin will last only until the system gets rid of the serum; and the cells of the body will not replace it after it is gone. The presence of toxin in the body causes the cells of the body to produce antitoxin, but the presence of antitoxin does not stimulate its own production. Hence, immunity gained by an injection of antitoxin is passive, whereas immunity resulting from vaccination is permanent, at least for a long time.

4. **Toxin Injection.**—We have mentioned the fact that when the horse is injected with the toxin of diphtheria an antitoxin is produced in its blood which counteracts the toxin, and that a superfluous quantity of the antitoxin remains in the blood. This renders the horse immune. It is an example of the fourth method of acquiring immunity, but is not resorted to very much in the practice of medicine.

Quarantine.—Every person who has a communicable disease got it from some one else who had it or from some animal which was *affected.* If people who have contagious diseases would be careful *not to spread them,* such diseases would disappear entirely. Biologi-

cally speaking, any one who gives a disease to another by breaking quarantine, spitting in public places, or by general carelessness may be as guilty of murder as if he had killed his victim with a shotgun. How long will it be before we are well enough educated as a people to rid ourselves of contagious diseases!

60. FUNGUS DISEASES OF PLANTS

How are fungi related to plant diseases?

There are about 250 common diseases of domestic plants and forest trees which are caused by fungi. Duggar lists 24 diseases of the apple alone. They constitute fully as great a problem to the farmer, gardner, and orchardist as do soils, climate, pure seed, or cultivation.

The annual losses of the farmers of the United States from fungus diseases amounts to over half a billion dollars. The loss from potato blight alone amounts to $36,000,000.

Potato Blight.—We will consider potato blight (*Phytophthora infestans*) as a type of fungus disease. It had its origin in South America and followed the potato to Europe and North America. It attacks the potato vines rather suddenly about the latter part of July, and in a short time they wither and die. For the past century the farmers of Ireland have lived mostly on the potato. When the blight swept over the island in 1845–46 it caused one of the most dreadful famines the world has ever witnessed. Some idea of the catastrophy may be gained by reading the following from Fitzmaurice and Thursfield in Larned's *History for Ready Reference.*

"The harvest of 1845 promised to be the richest gathered for many years. Suddenly, in one short month, in one week it might be said, the withering breath of a simoom seemed to sweep the land, blasting all in its path. I myself saw whole tracts of potato growth changed in one night from smiling luxuriance to a shriveled and blackened waste. A shout of alarm arose. But the buoyant nature of the Celtic peasant did not yet give way. The crop was so profuse that it was expected the healthy portion would reach an average result. Winter revealed the alarming fact that the tubers had rotted in pit and storehouse. Nevertheless the farmers, like

hapless men who double their stakes to recover losses, made only more strenuous exertions to till a larger breadth in 1846. Although already feeling the pinch of sore distress, if not actual famine, they worked as if for dear life; they begged and borrowed on any terms the means whereby to crop the land once more. The pawn offices were choked with the humble finery that had shone at the village dance or the christening feast; the banks and money-lenders were besieged with appeals for credit. Meals were stinted, backs were bared. Anything, anything to tide over the interval to the harvest of "Forty-six." O God, it is a dreadful thought that all this effort was but more surely leading them to ruin! It was this harvest of Forty-six that sealed their doom. Not partially but completely, utterly, hopelessly, it perished. As in the previous year, all promised brightly up to the close of July. Then, suddenly, in a night, whole areas were blighted; and this time, alas! no portion of the crop escaped. A cry of agony and despair went up all over the land. The last desperate stake for life had been played and all was lost. The doomed people realized but too well what was before them. Last year's premonitory sufferings had exhausted them and now?—they must die.

"We raised a public subscription, and employed two men with horse and cart to go around each day and gather up the dead. One by one they were taken to a great pit at Ardnabrahair Abbey and dropped through the hinged bottom of a trap-coffin into a common grave below. In the remoter rural districts even this rude sepulcher was impossible. In the field and by the ditchside the victims lay as they fell, till some charitable hand was found to cover them with the adjacent soil."

Millardet's Discovery.—Plant diseases were little known at the time of the Irish famine, and control measures still less known. It will be remembered that bacteria as the cause of human disease were not known until shortly before 1880. In 1883 Millardet, a Frenchman, discovered a chemical mixture composed of copper sulphate and lime which will prevent potato blight. He first used it to control a similar blight of the grape. From 1845 until 1883 the world was almost helpless to combat blights of all kinds. During this time botanists had worked out the life history of several

fungus diseases. A knowledge of the life history is usually necessary before control measures can be devised.

The Life History of Potato Blight.—The fungus may attack all parts of the potato plant. It winters over in the tubers and is planted with them in the spring. It grows as the plant grows until it produces its spores. Hypha project through the stomates in the leaves and bear structures called *conidiospores* (Fig. 305) which are capable of floating in air, and may be blown great distances. When a conidiospore falls on the leaf of a potato plant which is wet with

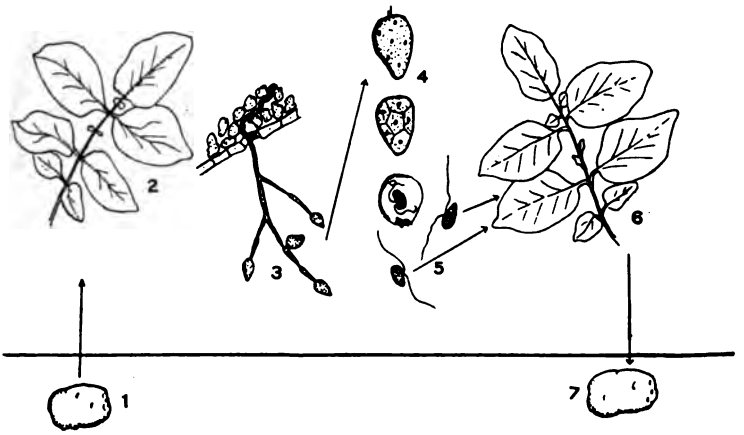

FIG. 305.—Life history of potato blight (*Phytophthora infestans*). 1, a planted tuber which has harbored the disease over winter. 2, a leaf of the plant which grew from the tuber (1) and which is infected. 3, a sporophore of the fungus growing from a stomate of the leaf and bearing conidia. 4, three stages in the germination of a conidium to form swimming spores (5) which infect a healthy leaf of another plant by swimming through drops of rain or dew to send a growth of mycelium through the stomates (6). 7, a tuber produced by this plant and a carrier of the disease to the crop of the next year.

dew or rain, it germinates and produces several two-ciliate spores which swim about over the surface of the leaf. They are, therefore, *zoospores*. If one of these zoöspores succeeds in entering a stomate of the leaf it will germinate and send forth a hypha which branches and grows through the fibrovascular tissues of the plant to all of its parts. In this manner it stops up the tubes through which sap *circulates*.

Since the zoospores are not formed except in the presence of water on the surface of the leaf, the disease is not spread in rainless and dewless weather; and since the spores are carried by the wind they will not spread far in calm weather; but, suitable weather conditions of wind and moisture are usually more or less favorable to the spread of the parasite, and these conditions are not under the control of man. If the tubers are diseased, most of them will rot, but some will be sound enough to plant. If diseased potatoes are

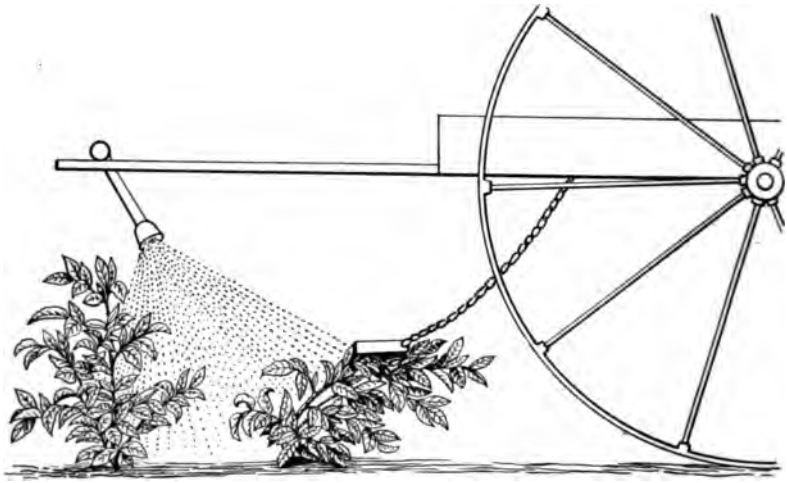

FIG. 306.—A good spraying apparatus for reaching the under surface of the leaves of potato plants. (*Courtesy of the Wisconsin Farmer.*)

not planted, the disease will be greatly reduced, but this method of control is not sufficient. Attempts have been made to breed a disease resistant variety, but thus far little progress has been made.

Bordeaux mixture is the name of the fungicide invented by Millardet. It is named after the City of Bordeaux, France. A disease in many ways similar to potato blight was brought over to France along with American grape vines which were resistant to it in America; but the European grape could not withstand it. It was in a successful attempt to control this disease that Bordeaux mixture was invented. This poison in the water on the surface of the

leaf kills the zoospores when they leave the conidiospores to enter the stomates. Millardet worked out a solution-mixture which was of such strength that it would do the foliage of the grape no harm but would kill the spores of the grape mildew. This mixture is now used to combat many fungus diseases of plants. The strength differs for different uses, but the following formula is most commonly used:—

Copper sulphate	5 pounds
Stone lime	5 pounds
Water	50 gallons

Mix thoroughly and apply in the form of a fine spray.

Bordeaux mixture is not a *cure* for any disease. It is a *preventive.* After a fungus has once entered a plant it is usually impossible to eradicate it except by pruning the parts which are affected; and, except in the case of trees, this is impracticable.

The conquering of potato blight marks another victory of science over the forces of nature. The potato has been restored to the fields of Ireland, and the people may rest assured that *Phytophthora infestans* will never cause another famine.

Project.—Begin making a collection of various types of fungus diseases. Properly label them and arrange them in a museum case.

61. THE CONTROL OF PLANT DISEASES

How may plant diseases be controlled?

In previous studies we have seen how science has brought human diseases under control; and we have just considered the importance of potato blight, and have seen how by knowing its life history it is held in check. If we did not know how to fight plant diseases such a catastrophy as the Irish famine might afflict us at any time through the destruction of several of our essential food crops.

In the cultivation of domestic crops the chances of contagion are much greater than in nature. An entire field is planted to one crop. In some sections a grain crop may cover a great area: field adjoining field. If a disease once gets started its spores may be carried by the wind over the entire region, bringing the danger of death to every

plant. The agriculturalist must be constantly on the watch for the first signs of danger. Fortunately, most plants possess more or less natural immunity to their diseases; and, consequently, the affliction does not spread as rapidly as it might.

FIG. 307.—A fire blighted apple twig. The bacteria travel down the twig in the sap ducts and spread rapidly in young tissue. (*After Vaughan, College of Agriculture, University of Wis.*)

There are several groups of fungi which affect our crops. Some are easily controlled, and some defy our most heroic efforts. Each group must be fought in a special way according to its life history and habit of attack. We will study six representative methods which may be called *pruning*, *spraying*, *seed disinfection*, *crop rotation*, *quarantine*, and *breeding for immunity*.

1. **Fire blight** is a disease of the apple, pear, and quince. It manifests its presence by a sudden wilting and blackening of the blossoms. After a time the twigs also turn black. It may ultimately travel down the twigs and kill the entire tree. It lives over winter in the diseased twigs and may be carried from tree to tree on the feet of birds and insects. It is caused by a bacterium (*Bacillus amylovorus.*) If the diseased portions of trees are carefully sought out and pruned away it may be eradicated. The black rots of plums, cherries, and apples are also controlled by pruning. Wood rot of trees may be carefully removed if not too bad, and the wound thoroughly disinfected, and filled with concrete. However, *if the trunk* shows shelf or bracket fungi, it is probably too late

to save it by surgery; and it should be removed to prevent a further spread of the infection.

2. **Spraying.**—We have already mentioned spraying as a means of preventing grape mildew and potato blight. Other diseases which may be prevented by spraying are the brown rot of peaches, cherries, and plums, early blight of potatoes, scab and bitter rot of apples, and the leaf curl of peaches. The class may study these diseases by means of field trips, preserved specimens in the laboratory, and reports from the latest government bulletins.

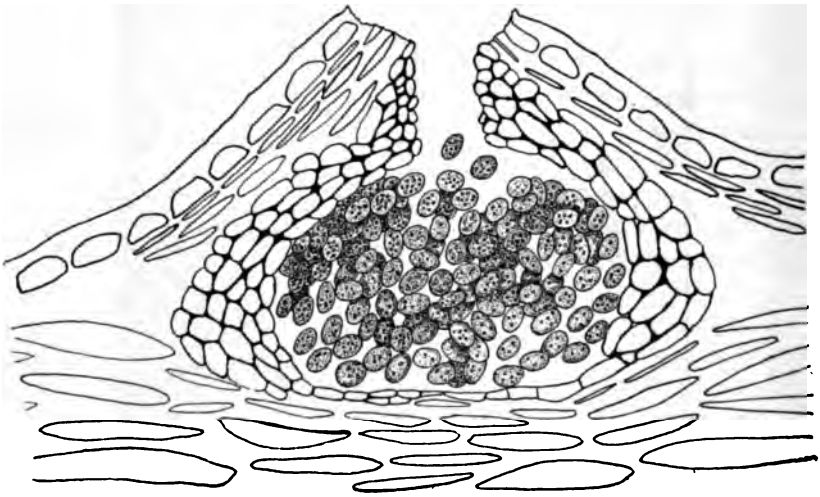

FIG. 308.—A section through a blotch in the skin of a young Ben Davis apple showing the spores ready to be released. (*Bulletin No.* 534, *U. S. Dept. of Agriculture.*)

Apple blotch is caused by a fungus. It appears as hard, brown spots on the fruit, cracked areas on the twigs, and brown or yellow spots on the leaves. It lives throughout the winter on the twigs and produces great numbers of spores in the spring. These spores are carried by the wind and other means to the fruit and leaves. If the trees are properly sprayed with Bordeaux mixture the disease can be controlled.

Lime-sulphur is another good spray mixture which is extensively used. It is prepared in a strong form for winter use against both

scale insects and fungi which winter over on the bark of twigs. Because this strength would kill vegetation if used in summer, a special mixture containing about 4 lbs. of lime, 4 lbs. of sulphur to 50 gal. of water is used. The lime-sulphur spray mixtures are usually purchased already prepared in a concentrated form and are diluted for different uses according to directions.

FIG. 309.—A smutted panicle of oats and a normal one to show how the grain is destroyed.

3. **Stinking smut of wheat** is caused by a fungus which produces its spores in the kernel. At thrashing time the dead kernels break open releasing the spores. They are distributed over the healthy kernels and germinate with them the next spring. The disease attacks the young plants, usually below ground, and lives in the

wheat plant until the kernels are formed when it again produces a crop of spores which destroy the grain.

Seed Disinfection.—If the seed wheat is soaked in formalin (1 lb. of formalin to 45 gal. of water) the spores will be killed and the next crop will be free from the disease.

Loose smut of wheat does not destroy the kernel, and its presence can not be detected within. No external application of a fungicide will kill this parasite, it can be destroyed by soaking the seed wheat in cold water for five hours, and then in hot water at a temperature of 129° F for ten minutes. If this is accurately done the seed will not be harmed, and the crop will be free from loose smut.

Each one of the grains is affected by smuts. Some should be made the subjects of special reports and laboratory demonstrations. With the exception of corn smut they can be controlled by one of the methods outlined above. More complete details can be found in the Farmer's Bulletins of the U. S. Department of Agriculture.

4. **Crop Rotation.**—*Cotton wilt* is a disease which attacks the roots of cotton and lives in the soil for many years. No method of eradicating it is known. For this reason, if a soil is affected no cotton must be grown on it for several years. This necessitates crop rotation. Some fungi which do not live so long may disappear in two or three years. Have reports given on flax wilt, root rot of tobacco, dry rot of potatoes, and club root of cabbage. See the latest government bulletin on each topic.

5. **Quarantine** is as effective in preventing plant diseases as it is in preventing human diseases. The Irish famine would not have occurred if potato blight had been confined to South America. The Japanese chestnut is fairly resistant to the chestnut bark disease. This disease has recently attacked the chestnut trees in America, and will probably kill all of our trees throughout the country, for no means of combatting it is known. It is of the utmost importance that we keep out diseases which are known in foreign countries, and a quarantine is now rigidly enforced against several by the U. S. Department of Agriculture.

6. **Breeding for Immunity.**—Cotton wilt and watermelon wilt have been controlled by breeding. The first by selection and the second by hybridization. The methods used were discussed in the

study on "Plant Breeding by Hybridization" and should be reviewed at this time. Our only hope of maintaining our chestnut trees at the present time is to hybridize them with the Japanese variety, and, thus, breed a disease resistant form.

FIG. 310.—A young cotton plant attacked by cotton wilt. (*After Orton, U. S. Dept. of Agriculture.*)

62. THE WEED PROBLEM

What harm do weeds do, and how may we fight them?

A weed is a plant which is an enemy to some crop is a good answer *to the question,* "What is a weed?"; but we must interpret the word

crop very liberally, for the dandelion growing on a lawn is a weed, yet we do not ordinarily think of lawn grass as a crop. Another way of defining a weed is to say that it is a plant growing where it is not wanted. Red clover, horse-radish, rye, and Johnson grass may be valuable crops depending upon whether they are planted, or grow where they are not desired.

A weed, in order to live, must possess the power to grow in spite of the efforts of man to destroy it. They are, in various ways, especially adapted to live in the places where they are found. Bergen and Caldwell in *Practical Botany* tabulate the chief qualifications of weeds as follows:

(1) The power of vegetative reproduction.
(2) Deep, tough roots, or relatively extensive development of the underground portion.
(3) The power to produce many seeds.
(4) Capacity for self-pollination (if necessary).
(5) Good means of seed dispersal.
(6) Capacity for rapid growth.
(7) The ability to resist plant diseases.
(8) Tolerance of shade (at least when young).
(9) Tolerance of drought.
(10) Tolerance of excessive water supply and lack of air in the soil.
(11) The ability to resist the effects of dust in choking the stomates.
(12) Capacity to thrive in poor soil.
(13) Ability to retain vitality of seeds buried in the soil, sometimes from fifteen to twenty-five years.
(14) Unpalatableness, offensive smell, prickles, or some disagreeable characteristics, which lessen the danger of being eaten by animals.

Field Trip.—Go out into the fields and gardens and gather as many different kinds of weeds as you can find. Write to the state department of Agriculture of Wisconsin, Minnesota, Michigan, and Ohio for their weed bulletins and look up the names of those which you have found. Classify them according to how many of the above characteristics they possess. Is your city a weedy City?

Damage Done by Weeds.—Some crops are entirely ruined by them, and all crops are interfered with more or less. It has been estimated that in spite of the best efforts of the farmer his losses due to weeds are at least a dollar an acre on the average. The *three general ways* in which practically all weeds affect crops are by *shading,* and *by robbing* the plants of soil water and mineral salts.

The sunflower, jimson weed, burdock, and cocklebur have very broad leaves, grow quickly, and starve out other plants which compete with them. Because weeds grow so rapidly, they require great quantities of salts and moisture from the soil. The more they get the less there is for the cultivated crops.

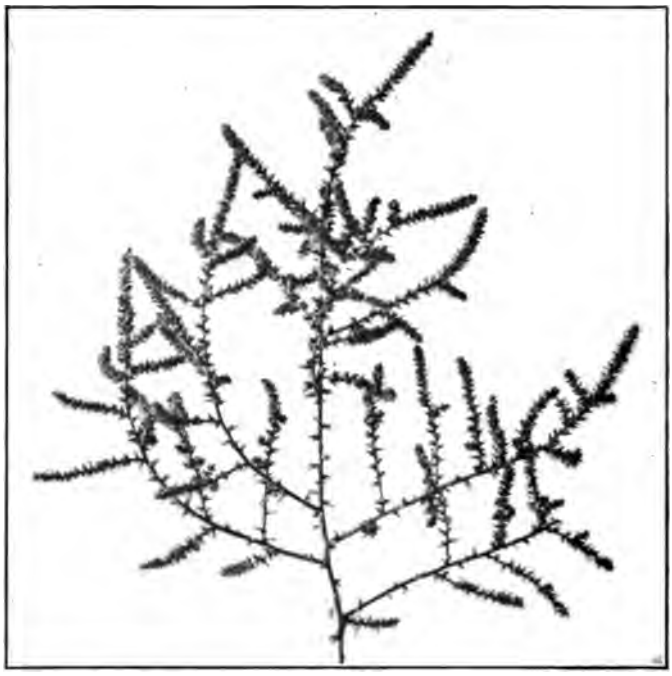

FIG. 311.—A spray of the tumble weed. How many of the fourteen qualifications does this weed possess?

THE SPECIAL MEANS BY WHICH WEEDS DO DAMAGE are many. We will consider only the most important cases.

Parasitic Weeds.—Clover dodder grows from a seed and sends a root into the ground. As it grows its stem twines around the clover plants and sends root-like processes, called *hausteria*, into their stems. It soon loses its root and becomes a parasite, living wholly

on the clover. Dodder is an example of a parasitic weed, of which we have but few, as yet, in North America.

Unsavory Weeds.—When cows eat wild onions or fennel the oils contained in the stems and leaves of these plants pass into the milk giving it a disagreeable taste and rendering it unfit for butter making or use in the manufacture of condensed milk.

FIG. 312.—The broad leaves of the sunflower prevent smaller plants which grow beneath it from getting sufficient sunlight for their existence.

Poisonous Weeds.—Live stock raisers are often troubled by the larkspurs, loco weeds, hemlocks, and laurels. Stock often eat these weeds when vegetation is scarce. Colts, calves, and lambs are more apt to be affected than adult animals. The juices of poison ivy, poison oak, and poison sumach cause blisters to form in the skin of

people who come in contact with them. Refer to Farmer's Bulletin No. 86 and to Professional Papers Nos. 125 and 365, if a more complete study of this topic is desired.

Weeds may be hosts to parasites. Several wild grasses harbor the Hessian fly over winter. In the spring it leaves the grass and attacks the wheat. (See Farmer's Bulletin No. 640, *The Hessian Fly.*) Wheat rust is harbored by the barberry and several wild

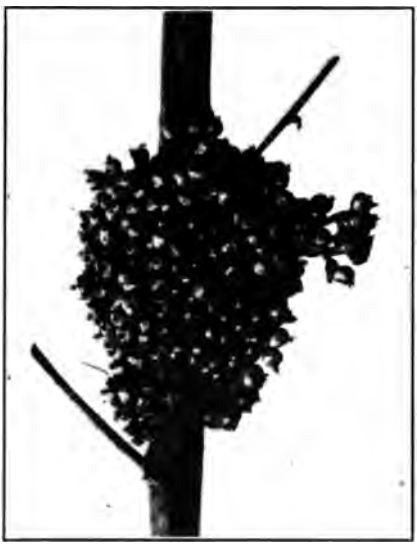

FIG. 313.—A cluster of seed capsules of dodder growing on a weed stem. It is a well recognized biological principle that parasites produce a great abundance of seeds or eggs.

grasses. The wheat rust fungus lives on the barberry over winter and leaves this plant in the form of spores in the early summer to attack the growing wheat. Write to the U. S. Department of Agriculture for literature on the relation of the barberry to wheat rust.

Survey.—Appoint committees to cover your city and see if there are any tall-bush barberries in the city. If there are they should be *removed. Does* your state have a law requiring this to be done?

How can you find out? One way is to appoint a committee to consult some public spirited lawyer. (See Fig. 316.)

Burs are produced by the burdock, cocklebur, and sand-bur. Such burs accumulate in the manes and tails of horses and in the

FIG. 314.—Poison ivy. Note the seed capsules and that the leaves are three parted. (*U. S. Dept. of Agriculture.*)

tails of cattle. They are very difficult to remove. They depreciate the value of wool if they occur in sheep pastures. Sheep may lose much wool by rubbing against spiny and thorny plants which pull it out. (Fig. 195.)

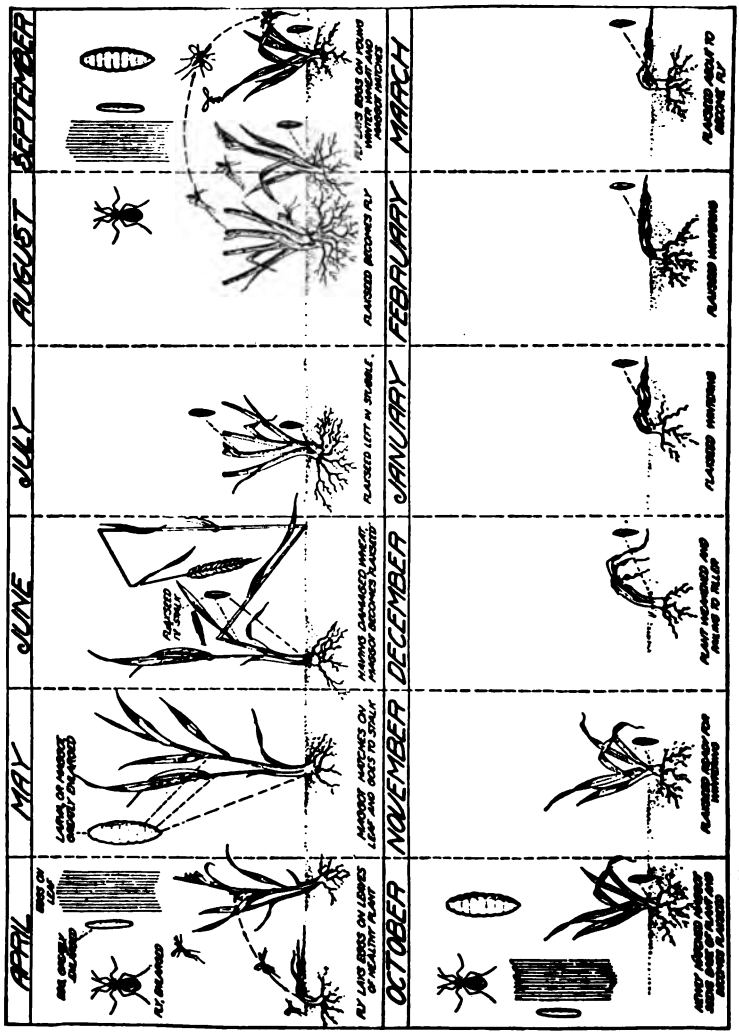

FIG. 315.—The life history of the Hessian fly. (*U. S. Bur. Ent., Lochhead.*)

Weed seed is often mixed with the seed of clover and other crops. About fifty different kinds of weed seed may be found in clover seed, and about twenty-five in timothy seed. If weed seed is planted with

FIG. 316.—Digging up the barberry which harbors wheat rust. It must be taken out roots and all or it will grow again. (*U. S. Dept. of Agriculture.*)

the clover it will be all the more numerous the next year. Many farmers unwittingly plant much of their weed crop each year.

Weeds damage the appearance of farms, parks, and lawns. Dande-

lions are common nuisances on lawns, and jimson weeds are well known for their presence around barnyards.

The pollen of ragweed is believed to be a cause of hayfever.

Weeds interfere with the work of the farmer. Their presence in the shocks retards the drying of grain after it is cut. They increase the labor of thrashing. Their presence in cured hay and straw depreciates its value. Potatoes, beets, and carrots are removed from the ground with greater difficulty if weeds are present.

The Solution of the Problem.—We have made out quite an indictment against weeds. What are we going to do about it? Must we

FIG. 317.—Mixture of weed seeds commonly found in low-grade alsike clover seed: *a*, alsike clover; *b*, white clover; *c*, red clover; *d*, yellow trefoil; *e*, Canada thistle; *f*, dock; *g*, sorrel; *h*, buckhorn; *i*, rat-tail plantain; *k*, lamb's-quarters; *l*, shepherd's-purse; *m*, mayweed; *n*, scentless camomile; *o*, white campion; *p*, night-flowering catch-fly; *q*, oxeye daisy; *r*, small-fruited false flax; *s*, cinquefoil; *t*, two kinds of peppergrass; *u*, catnip: *v*, timothy; *x*, chickweed; *y*, Canada bluegrass; *z*, clover dodder; 1, mouse-ear chickweed; 2, knot-grass; 3, tumbling amaranth; 4, rough amaranth; 5, heal-all; 6, lady's-thumb. (Enlarged.) (*U. S. Dept. of Agriculture.*)

always have weeds? Perhaps we must, but we can do much to reduce their numbers. It is estimated that it cost $75 per year to fight weeds on a 100 acre farm in Ontario. Must man always pay this toll to weeds? The future holds the answer to this question.

Weed Control.—Sheep eat weeds in preference to grass. They *should be allowed to graze* where they will kill weeds and not damage

other crops. Weeds may be sprayed with a prepared solution of copper sulphate which will kill some of them and not harm certain crops, such as grain. All weed seed should be removed from grain before it is fed or it will be planted with the manure. Only clean seed should be planted. Crop rotation is another way to fight weeds. Few weeds are able to grow among all crops. Many weeds, such as cockle and dodder are peculiar to certain crops and can not live if rotation is practiced. Fence rows should be eliminated if possible, and roadsides should be mowed before the weeds go to seed. If they have gone to seed they should be cut, dried, and then burned. Be an enthusiastic supporter of all reasonable projects which are aimed against the weed.

63. SOME WORMS WHICH INFEST MAN

How do parasitic worms get into the body of man?

Tapeworms are found as adults in the intestines of many of the vertebrate animals. They require two hosts to complete their life history, and alternate with some animal that is eaten by the vertebrate host. *Tænia solium* is parasitic in the alimentary canal of man, and passes its larval stage in the pig. As shown in the illustration, it is a long, flat worm composed of many sections. At one end is a structure modified for attachment to the wall of the alimentary canal. It is called the "head" or *scolex*. The sections originate from the scolex, and grow in size as they are pushed away by the formation of new ones. The worm may attain a length of several feet.

The tapeworm is a typical parasite. When it is once established in the food canal of a vertebrate animal its troubles are over. It has no enemies there, and there is plenty of food. It has no need for eyes, ears, or any sense organs whatever, hence it has none. It floats in an abundance of food, which it absorbs through its body-wall, hence it needs no intestine, and has none. Its nervous and circulatory systems are all but gone. The excretory system is still intact, for it must get rid of its waste products; but it is reduced in size in keeping with the slow metabolism of the worm.

The sections which are called *proglottids* are little more than sacs

filled with eggs when they are mature. As shown in the illustration, each proglottid contains both male and female reproductive organs. It is, therefore, said to be *hermaphroditic*.*

The eggs are formed in the bilobed *ovary* and pass into the *oviduct*, where they are surrounded with yolk from the *yolk gland*. They are then covered with a shell by the *shell gland*, and pass into the *uterus* where they remain until the proglottid passes out of the body.

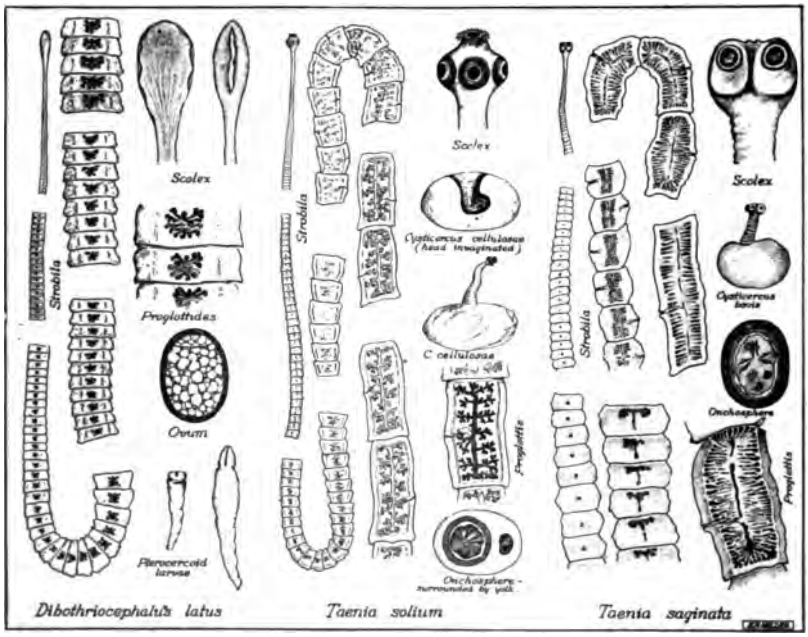

FIG. 318.—The three tapeworms which infest man. (*Stitt.*)

Sperms are produced by small bodies called *spermaries* which are scattered throughout the proglottid, and are collected by many small tubes which unite to form the long, coiled *vas deferens*. The sperms are carried to the exterior by the vas deferens. They pass into the *vagina*, and collect in the *sperm receptacle*, a sac near its inner end.

* From Hermaphroditus of Greek and Latin mythology who was united with the nymph Salmacias to make one person.

The eggs are probably fertilized near the junction of the oviducts and the vagina, before the yolk is deposited around them.

When the proglottids become mature they pass out of the body of man, and may be taken into the body of a pig; or a single egg may become separated from the proglottid and enter the mouth of a pig

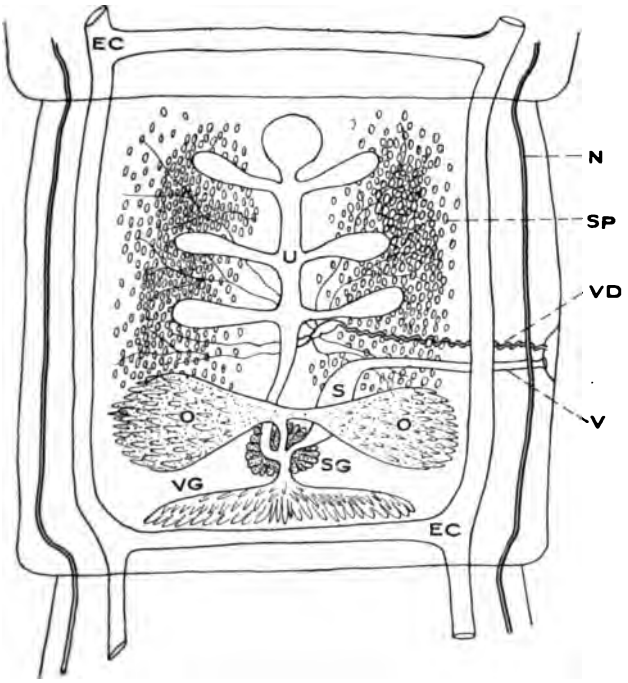

FIG. 319.—A proglotid of *Tænia solium*, the pork tapeworm.
EC, excretory canal;
N, nerve tract;
O, ovaries;
S, sperm receptacle;
SG, shell gland;
SP, spermaries;
V, vagina;
VD, vas deferens;
VG, vitelline gland;
U, uterus.

with the water or food. If this happens the egg develops into a microscopic worm which bores its way through the alimentary canal of the pig and comes to rest in a muscle. If the meat of the pig is eaten *by man without* being cooked, the larva emerges from its

cyst in the muscle tissue and develops into an adult in the alimentary canal of man.

There has been some dispute among zoologists as to whether a tapeworm is one, or many worms attached together. The scolex

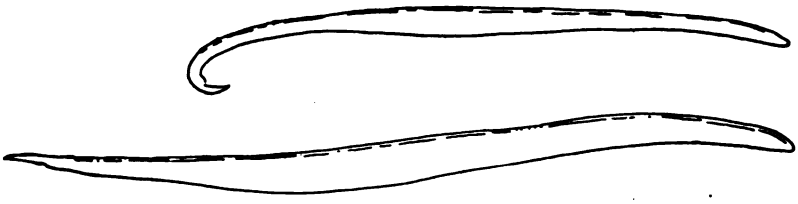

FIG. 320.—Male and female *Ascaris lumbricoides*, the round worm which lives in the intestine of man. The small one with the hooked tail is the male. The adults attain a length of from six to ten inches.

may be looked upon as an asexual generation which buds off proglottids which are sexual. Thus there is an alternation of generations.

Ascaris is a genus of roundworms which is widely distributed in nature. They inhabit the intestines of many vertebrate animals,

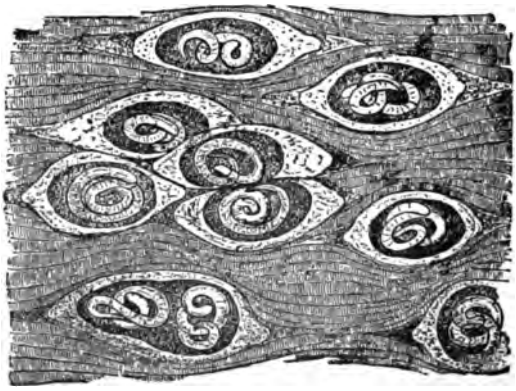

FIG. 321.—Larva of trichina encysted in the muscle of pork. (*From Stitt, after Ziegler.*)

and usually do not require an intermediate host to complete their life history. They lay large quantities of eggs which pass out with the excreta. If these eggs enter the mouth of another man and are

swallowed, they hatch, and become parasites in the intestine. The sexes are separate.

Aside from the fact that the female *Ascaris* lays large numbers of eggs it has few of the characteristics of parasites, and lives an active life in the intestine of its host. They are often a source of great annoyance to children, but can be easily killed and expelled by giving santonin followed by a physic.

Trichina (*Trichinella spiralis*) is another roundworm of small size which may be a parasite in man. It is gotten by eating uncooked pork in which the larvæ are encysted. When the pork arrives in the stomach, the cyst is dissolved by the digestive juices, and the worm is released. They are male and female, and after mating the female produces many young which hatch from the egg before it is laid. The young bore through the intestinal wall and come to rest in a muscle. This same process is gone through in each host which the trichina enters. Many young trichina boring in the muscles set up a fever which often proves fatal to man. Compare the life history of trichina with that of the tapeworm.

The hook-worm (*Necator americanus*) is a parasite of the intestines of man in the southern states. It bores into the wall of the intestine and feeds on the blood of its victim. It also injects a fluid into the wound to prevent coagulation of the blood so it can feed freely. This causes a considerable loss of blood, and exposes the intestines to infection by bacteria. People who are badly infested with hook-worm are anemic, stunted, have swollen abdomens and a shiftless disposition. It is estimated that two million people in the United States are infested with this parasite. It can be expelled by giving thymol followed by Epsom salts.

The hook-worm's eggs pass out of the intestine with the feces. They hatch, and the larvæ live in the soil for some time. If they come into contact with a person's foot, they bore through the skin, enter the blood vessels, and are carried to the lungs where they bore through the tissue to the interior of these organs, and make their way to the stomach through the trachea and esophagus. The infestation can be greatly checked by a proper disposal of sewage, and a checking of the practice of going barefooted which is so prevalent among the people of the southern part of the United States.

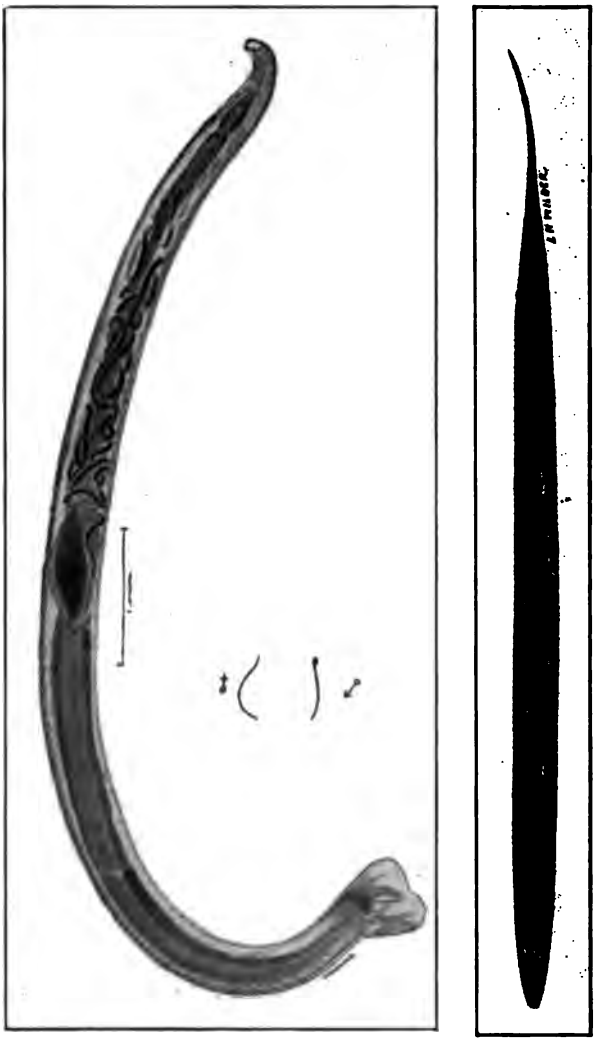

FIG. 322.—The hook-worm, *Necator americanus*, adult above, and larva below. (*U. S. Public Health Service.*)

Laboratory Suggestions.—Let the students work out diagrams of the life histories of the tapeworm, trichina, and the hook-worm. Put some of them on the board and discuss them in class. The students may draw the anatomy of the tapeworm from the model made by Ward's Natural Science Establishment, Rochester, N. Y.

FIG. 323.—Three victims of the hook-worm. Note the puffiness about the eyes and the lazy appearance of their poise and dress. (*U. S. Public Health Service.*)

64. INSECT ENEMIES OF DOMESTIC PLANTS

How do insects damage crops?

The Problem.—"Specific examples of insect depredations give one some notion of the total. Thus, in a limited area in southern Indiana and near-by countries, a species of cutworm attacking corn caused a loss in one year, 1908, of $200,000. The tobacco flea beetle in a single season, in Kentucky and Tennessee, inflicted damage to the extent of $2,000,000. Injury by a plant louse, the pea aphis, in two years of abundance, was estimated at $7,000,000. In the Black Hills National Forest, a species of beetle has destroyed timber representing at least 1,000,000,000 feet of lumber. The annual price of the boll weevil to cotton growers is figured at $15,000,000 to $30,000,000. Losses due to the cattle tick reach a total of $40,000,000 each season. In a single year of excessive abundance the Hessian fly exacted from our farmers an estimated total of $100,000,000. In Ohio the yield of wheat in that one season dropped from 15 bushels per acre to 6. The ravages of the chinch

bug in our crops of wheat and corn in the last 60 years are believed to reach the sum of $350,000,000."—*Injurious Insects*, by W. C. O'Kane.

The value of our agricultural crops is now considerably over $10,000,000,000. If we estimate the losses due to insects at only one tenth of the total value, the price which they exact of the farmers every year amounts to over $1,000,000,000. This amount of money, if it could be saved, would build three Panama Canals, rebuild all of the colleges and universities in the United States, or rebuild all of the buildings destroyed by fire in the entire country in four years.

The Solution.—We have seen in the two previous studies that a knowledge of the life history of a fungus parasite is necessary in order to fight it successfully. It is just as necessary to know the life history of an insect. In this study we will outline the life histories of a few types and will discuss the measures to be used against them.

The potato beetle feeds on potato vines. The eggs are a golden-yellow color and are laid in masses on the under side of the leaves. The young are heavy-bodied, red grubs. They feed on the vines and do more damage than the adults. When the grubs are grown they burrow into the ground to pupate. There are two broods each season. The adults winter over in the ground and emerge in the spring and begin laying eggs as soon as the plants come up.

This beetle appeared in fields between the Mississippi River and the Rocky Mountains about 1870. It formerly fed on the wild plants of the genus *Solanum* to which the potato belongs, but changed its food habits to take advantage of the more abundant domestic crop. It spread eastward rapidly and soon reached the eastern states. It was at that time feared that the potato could no longer be raised on a commercial scale. Some, remembering the Irish famine due to the blight, even prophesied famine in America. Until the potato beetle appeared, the science of economic entomology did not exist. It was necessary to find some successful method of fighting the bettles or give up raising potatoes on a large scale. Many methods were tried and found to be useless or of little value. Finally, Paris green was dusted over the leaves on which the insects [illegible]*re feeding. They* could not avoid eating some of the poison and [illegible] *killed.*

The successful control of the potato beetle by means of Paris green marked the beginning of man's scientific contest with insects for the salvation of his crops. Before this time few European and Asiatic enemies of domestic plants had appeared in America, and our native species did little damage. What damage was done was usually attributed to providence.

The San Jose scale (Pro. Sän hōsā) is an insect which is covered with a thin, flattened, conical scale. It has a sucking beak which it inserts into the bark of twigs or the skin of fruit and sucks out the sap. It winters over in the form of immature individuals which become adult and produce enormous numbers of young in the spring. The young crawl out from under the scale of the mother and wander over the tree for a time, then settle down and begin feeding. They grow rapidly and become mature in about thirty days. There may be from two to six generations in a summer, depending upon the length of the season.

Nearly a thousand kinds of scale insects have been discovered and named, but the San Jose scale does more damage than any other. It was first found near San Jose, California, and is believed to have come originally from China where it is found but does little damage; perhaps because it is held in check by its natural enemies and the native trees have developed a certain degree of immunity to it. In America it attacks many kinds of trees and is especially fatal to the peach. We have mentioned before that the number of peach trees in Michigan was reduced from 8,000,000 to 3,000,000. This was largely due to the ravages of the San Jose scale. Some trees were killed outright, others were so weakened that they died of the cold in winter. Apple trees usually die slowly and may linger for several years.

Control.—Scale insects can be controlled by spraying the trees in the spring, just before the buds swell, with lime-sulphur solution. If they are very numerous the tree may also be sprayed in the fall after the leaves have fallen. But for the discovery of a method of controlling the San Jose scale and others of similar habits it would be impossible to successfully raise peaches and apples in most parts of the United States.

White grubs *are the* larvæ of several species of beetles belonging

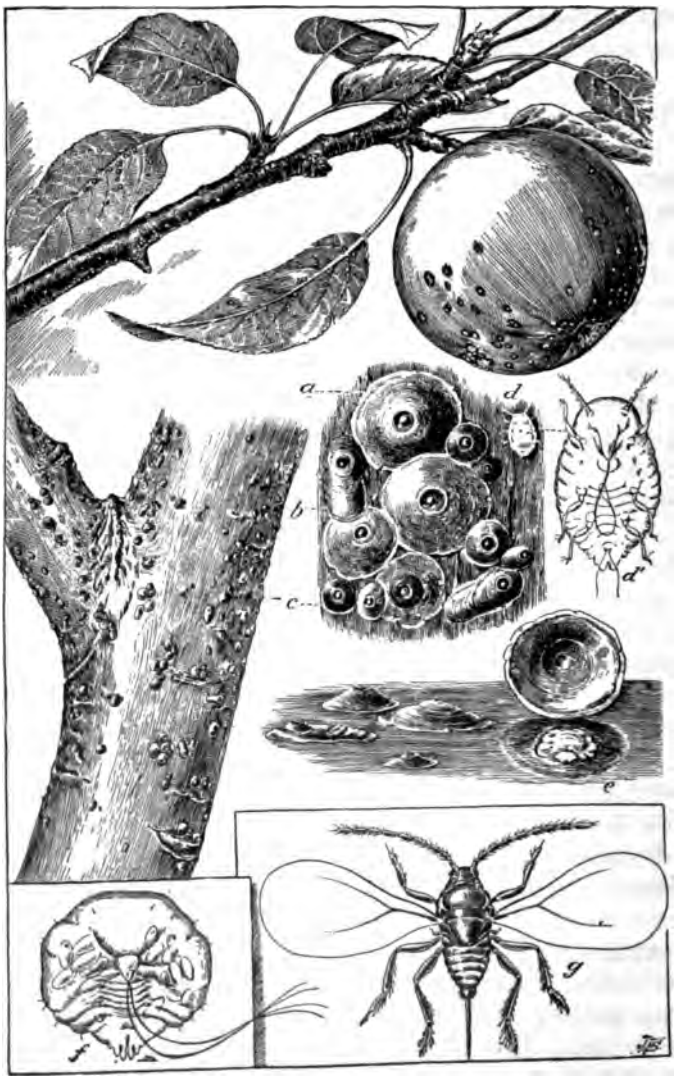

FIG. 324.—Life history of the San Jose scale. (*U. S. Dept. of Agriculture.*)

Above is an apple with the characteristic red spots which indicate the scales. *To the left is a branch* with scales on the bark. *a*, is an adult female scale; *b, a young male.* Note the difference in shape. *c*, young scales, sexes similar; *e, side view of male* and female scales, and a female scale lifted up to show the *insect beneath. d, d'*, young scale in the crawling stage; f, an enlarged female *scale; g, a male with wings.*

to the genus *Lachnosterna*. The adults appear in the spring in great numbers and eat the foliage of various trees, sometimes completely defoliating them. The eggs are laid in the ground during the day. The grubs feed on the roots of various plants, but the normal food of the majority of them is grass roots, hence they commonly lay their eggs in hay fields and pastures. The grubs live

FIG. 325.—An apple tree which is dying because of infestation with the San Jose scale. This tree is a source of infestation to all apple trees in the vicinity and should be removed.

in the soil through two summers and change to beetles in the second fall but remain in the ground until spring, making the life cycle three years.

White grubs are a bad pest to corn, potatoes, and strawberries. At times they seriously affect other crops, particularly timothy and the small grains. Farmer's Bulletin No. 140 reports that in the worst infested areas it is not unusual to find from 40 to 60 grubs in a single hill of corn and estimates the annual loss due to these pests *at not less than $12,000,000.*

Control of the white grub is not so simple a matter as that of the potato beetle and scale insects. It is possible to kill the adults by spraying the trees on which they feed with a stomach poison, but it would be too expensive to spray groves and forests for this purpose. The males may be attracted to lights at night in great numbers and killed by arranging a water tank for them to fall into. This would be more effective if the females could be caught also. Since the grubs feed beneath the ground it is impossible to reach them with a poison of any kind, but by knowing their life history it has been pos-

FIG. 327.—The white grub eating a potato.

sible to work out measures for their control. Since the eggs are laid in grass land, and the grubs feed two years, crops which they affect should not be planted on land which has been in grass until the second year; and since the grubs do not go beneath the plow-line in the fall until the end of September, the land should be fall-plowed before this time. This will kill many and expose many more to the attacks of birds. Chickens and pigs will eat great quantities of them if they are given the run of the fields.

65. THE CONTROL OF INJURIOUS INSECTS

How may man save his crops from insect pests?

The poisons used to kill insects are of two kinds, depending upon *the shape of the* mouth-parts and the methods of feeding of the

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pests. Those which eat foliage can be fed a lead or copper poison which is called a *stomach poison*. Those which feed by sucking the juice of plants can not be so killed because poisons placed on the outer surface of leaves, twigs, and etc. will not be taken into their stomachs. These insects must be sprayed with a *contact poison* which is strong enough to kill them by coming into contact with their bodies.

Stomach poisons came into use with the discovery that Paris green would kill potato beetles. Paris green may be used in the

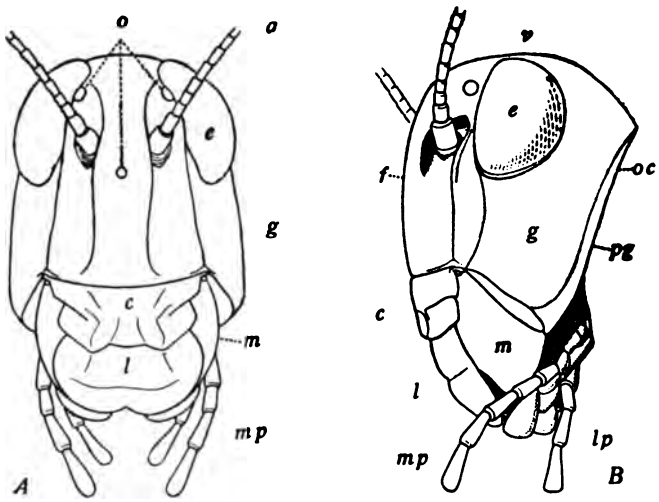

FIG. 328.—Front and side view of a grasshopper to show the parts of the mouth of a chewing insect. *a*, antennæ; *c*, clypeus; *e*, compound eye; *f*, frontal plate; *g*, genea; *l*, labrum; *lp*, labial palpus; *m*, mandible; *mp*, maxillary palpus; *o*, *ocelli*. (*From Folsom.*)

powdered form or it may be mixed with water and sprayed on the plant through a nozzle which throws a fine spray.

Lead arsenate is now used more than Paris green. It is not quite so powerful a poison, but it is cheaper and does not hurt the foliage of plants as much as Paris green. Since no lime is needed it can be made into a more perfect solution. It is now customary to use Bordeaux mixture with Paris green or lead arsenate. This combination spray will control both chewing insects and fungus diseases.

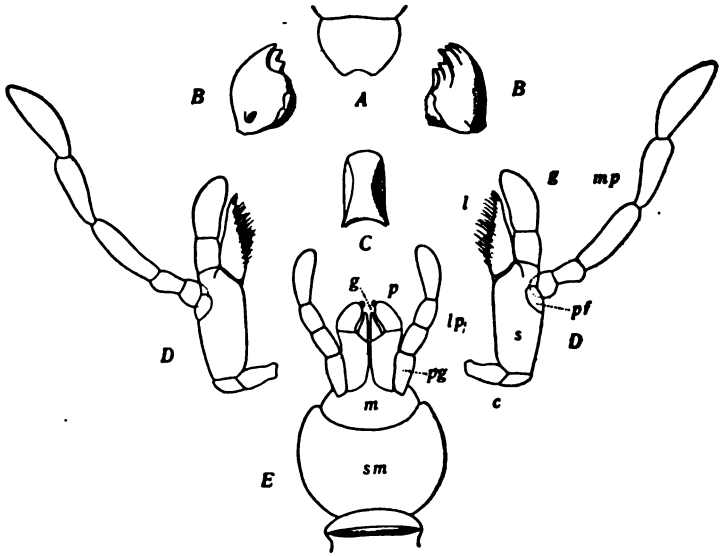

FIG. 329.—Mouth parts of a cockroach dissected as a type of chewing insect. *A*, labrum; *B*, mandibles; *C*, hypopharynx; *D*, maxilla; *E*, labium; *c*, cardo; *g* (of maxilla), galea; *g* (of labium), glossa; *l*, lacinia; *lp*, labial palpus; *m*, mentum; *mp*, maxillary palpus; *p*, paraglossa; *pf*, palpifer; *pg*, palpiger; *s*, stipes; *sm*, submentum. (*From Folsom.*)

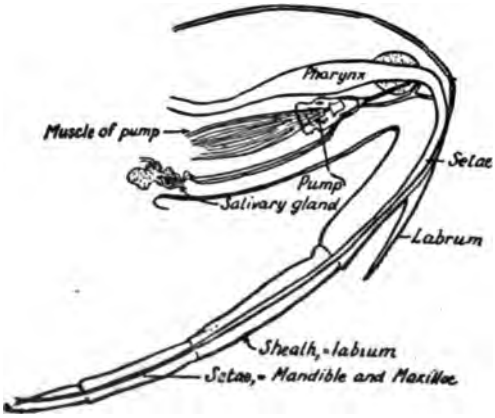

FIG. 330.—Mouth parts of the piercing and sucking type from one of the bugs. Note that the maxilla and mandible are united together to form a sucking tube. (*From Lochhead.*)

It has become customary to spray for the control of the codling moth, potato beetle, plum curculio, and flea beetles. If time permits reports on the life history of each of these pests should be made by some member of the class. See the following bulletins of the Bureau of Entomology, U. S. Dep't. of Agriculture: 41, 103, 19, and circulars Nos. 123, and 87.

Contact poisons are used chiefly against the various kinds of bugs and flies. We have mentioned the use of lime-sulphur in the control of scale insects. Soap solutions, kerosene emulsions, and nicotine solutions are the other forms most commonly used.

Kerosene emulsion may be made by dissolving ½ pound of hard soap in one gallon of water and adding two gallons of kerosene. This is the stock solution and must be diluted. The dilution varies from five to fifteen gallons of water to one of the stock solution according to use. Plants with delicate foliage can not withstand an application of a strong solution. Nicotine, soap, and lime-sulphur solutions are on the market in concentrated form and must be diluted according to directions.

Aphids and leaf hoppers do damage to potatoes, fruits, berries, and vegetables. They often reduce the yield of potatoes to one-third of what it should be. They are controlled with difficulty by the use of kerosene emulsion. If possible, go on a field trip and demonstrate the use of sprays.

Repellents are chemicals used to drive insects away. The best known repellent is moth balls, or napthaline. Its odor drives away clothes moths. Lime may be used to drive away the striped cucumber beetle. Tobacco dust is a repellent to the root maggots which attack cabbage, radish, turnips, and onions. Whitewash, containing various chemicals, is often used on tree trunks to drive away the egg-laying adults of borers.

Fumigants are poisons which can be vaporized. The ones in common use are carbon bisulphide, carbon tetrachloride, hydrocyanic acid gas, and the fumes of sulphur and tobacco. Ants may be destroyed by making a hole in the center of an ant hill with a stick, pouring in carbon bisulphide, and closing the top of the hole. The fumes will penetrate to all parts of the nest and will probably kill the queen. This will put an end to the colony.

Young fruit trees which are imported are usually fumigated to avoid the possibility of bringing in some foreign pest. Growing trees are sometimes covered with a tent and fumigated to kill all insects which they harbor. Warehouses and flour mills are sometimes fumigated by heating them to a high temperature when they have become overrun with insects which live in stored food.

Crop rotation is resorted to to control insects which live in the ground and feed on the underground parts of plants, or against insects which do not travel great distances. We have mentioned its use in combating the white grub. Have a report given on the value of crop rotation to fertility of soils. A report may also be given on the control of wireworms by crop rotation.

Fall plowing destroys many delicate insect larvæ and disturbs others so that they may be eaten by poultry, birds, or hogs. If the plowing is done late many will not get below the frost line before they are frozen. Fall plowing is of value against wireworms, white grubs, potato beetles, grasshoppers, tomato worms, and ants.

Removal of crop wastes and remnants is of value in fighting the codling moth of the apple. The apple worm, which is the larva of the moth, may be found in the wind-fall apples. If they are allowed to lay on the ground the larvæ emerge, change to chrysalides, and become adult in time to lay eggs for the second brood before the main crop is ripe. The adults of several pests winter over in trash, along fence rows, under leaves, and in brush piles. These places should be destroyed. Appoint a committee to examine such places and report what they find.

Weeds harbor insects in various ways. If the expense is not too great it is a good plan to destroy all weeds. Assign reports on the relation of the following insects to weeds: Hessian fly, potato beetle, carrot caterpillar.

Birds and poultry are great destroyers of insects. Quail earn their weight in gold. They should be everywhere protected by the farmer, and should never be shot unless they become so numerous as to do damage to grain. The wise farmer does not permit quail shooting on his premises. The black and yellow billed cuckoos eat woolly caterpillars in great quantities. Even crows and sparrows *are man's friends* when an insect war is on. It is questionable

FIG. 331.—A pair of California quail. Are quail protected in your state?

FIG. 332.—The black billed cuckoo, destroyer of wooly caterpillars.

whether the shooting of any wild birds, with the exception of four hawks, should be permitted. Most hawks are known to be highly beneficial.

Fertilizers stimulate plant growth. In many cases the insect injury is done during the time when the plant is small. If it grows vigorously during this time it may survive an insect attack. This is of special importance in the case of wireworms, white grubs, cut-

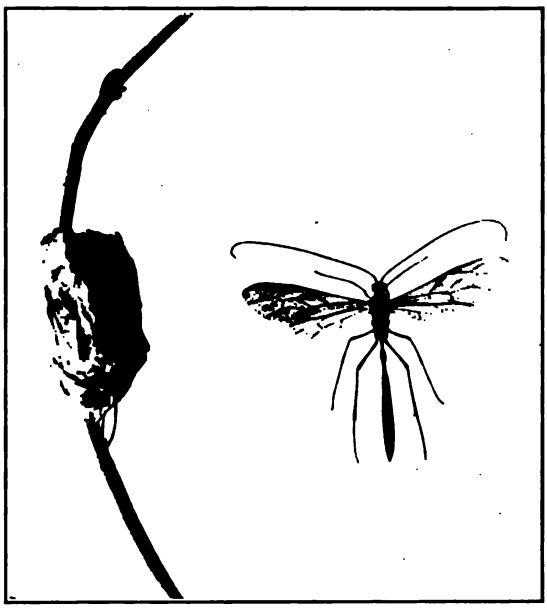

FIG. 333.—A cocoon of the lunar moth and an ichneumon fly which emerged from it. The larva of the ichneumon fly devoured the chrysalis of the moth. The collecting of caterpillars and chrysalides and saving them to see what ichneumons may be developed from them, instead of butterflies and moths, is an interesting project.

worms, aphids, and the Hessian fly. Sometimes planting the crop a little early or a little late is of great value. Have a report given on fighting the Hessian fly by this method.

Ichneumon flies and many other species of flies parasitise other *insects. There is hardly* a single species of insect which does not

have them for its enemies. Their usual method of attack is to lay their eggs on or in the larva. As the young fly develops, it feeds on the juices of its host, finally killing it. But for these "friends of man" most all forms of insects which live on vegetation would be so numerous as to become pests. *Nature maintains a balance among the number of living things,—i.e.*, the number of individuals in any species remains about constant from year to year; and it is prevented from overproducing itself by the attacks of its enemies.

Laboratory Study.—Study the mouth parts of a chewing insect,—such as a grasshopper, beetle, or caterpillar. Compare them with the sucking mouth parts of a bug. The squash bug, giant electric light bug, or cicada are good.

Begin building up a collection of injurious insects mounted by the students. Protect them from moth and beetle larvæ pests by spraying the specimens with bichloride of mercury solution. An atomizer makes a good spray instrument

Make a field trip to study the use of sprays against insect pests.

Individual Project.—Investigate the life history of some insect pest and report what you have found to the class.

66. THE FLY

Why is the fly man's worst enemy?

Flies are two winged insects, and belong to the order DIPTERA (di petron = two winged). Some are beneficial, parasitising many forms of insect larvæ; and some are parasites on domestic animals. The screw-worm flies, bot-flies, warble flies, and biting flies of various kinds are pests to live stock. One form of bot-fly lays its eggs on the legs and flanks of horses. The larvæ emerge from the egg when the horse licks these parts of the body and enter the stomach where they attach themselves to the stomach wall. Here they remain all winter and pass out with the horse's excreta in the spring to pupate in the ground. When bot-fly larvæ are present in large numbers they cause horses to loose flesh. In cases of severe attacks the horses may be killed.

Problem: Is there a method by which the horse bot-fly can be controlled? (See Entomology Bulletins Nos. 5 and 597, U. S. Department of Agriculture.)

Some flies, such as syrphus flies and robber flies eat insects, some are known as flower flies and live on nectar, and the young of some are known as maggots affecting fruit, grain, and vegetable crops.

The crane flies, midges, and mosquitoes are also two winged flies. The order DIPTERA is, indeed, a large and economically important one; but of all of its members none are of so much importance to man as the common house fly.

The house fly is found on all continents and goes wherever man does. It is a pest which man will always have to contend with and

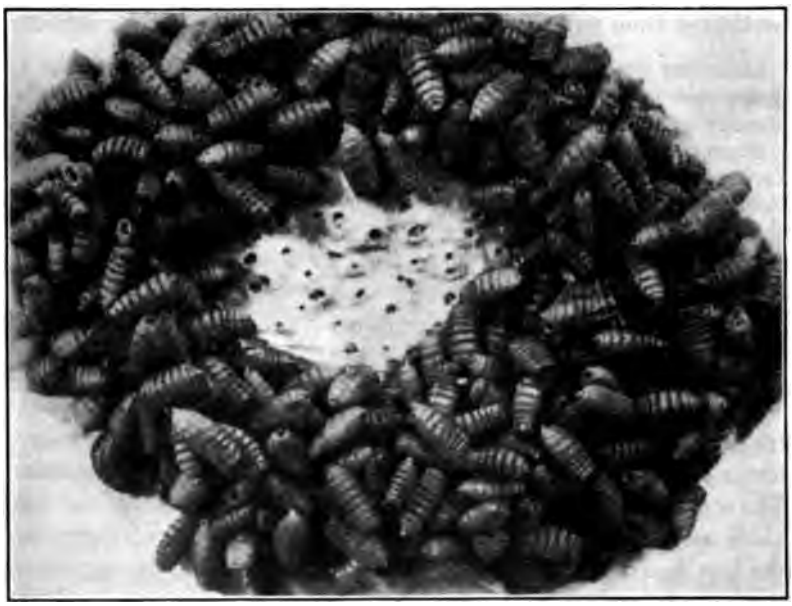

FIG. 334.—Bot fly larvæ on the wall of a horse's stomach. Note the lesions in the center where some have been pulled off. (*U. S. Dept. of Agriculture.*)

is the greatest living enemy of mankind. Twenty-five years ago the fly was thought to be harmless. Some naturalists, thinking all life must be of some value to man, even wrote about the usefulness of the gentle creatures! The author remembers being taught when he was a boy to rescue them from drowning in milk pans. All this has changed with an increase in biological knowledge. The biological facts which are known about the fly alone are worth more to the world than the cost of all of its schools and universities combined.

But let us examine the life history of the fly, and then make out our indictment.

Life History.—The female fly lays about 120 eggs at a time and usually lays four times. How many eggs all together? It is estimated that about 95% of the eggs are laid in horse manure. One pound of this material may support 1,200 fly larvæ. If your city still has manure piles estimate the weight of the nearest one, and calculate the number of flies which it produces. Estimating 8,000 flies to the quart, how many quarts would this be?

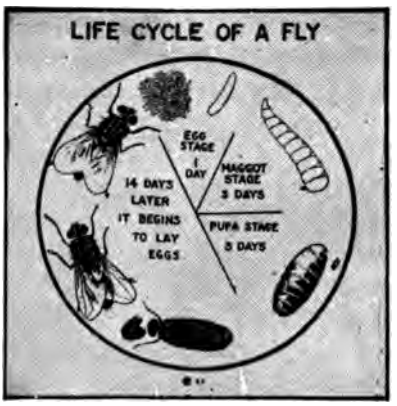

FIG. 335.—The life cycle of the fly. (*International Harvester Co.*)

Editorial Project.—Can a volunteer committee be pledged to get some information in regard to the relation of flies to manure piles into the city press?

The time of development of the fly from the egg to the adult varies considerably with the abundance of food, but under favorable conditions a fly may become adult in ten days. At this rate there may be ten to thirteen generations in a summer. Each fly passes through four stages in its metamorphosis. They are approximately: egg, ⅓ day; larva, 5 days; pupa, 5 days; adult, length of life varies from a few days to all winter. A few flies winter over in the form of the adult, but most of them winter over in manure piles in the form of pupæ.

Civic Projects.—If the fly can not find horse manure it will lay its eggs in other manure, garbage, or slops. Are there any cow, horse, or goat stables in your city? Are they kept in a sanitary condition? Are the hen coops kept clean? Is the garbage properly cared for? How should it be cared for? Are all residences connected with the sewer? Appoint committees to make this survey thoroughly if it takes a week.

House flies carry disease germs.

This is the complete indictment in one sentence. So far as is known they do no other harm to man. Their presence would be annoying only. It is not known that such specialized diseases as malaria, yellow fever, Texas fever, and cancer can be carried by flies, but most all other contagious diseases are carried by them.

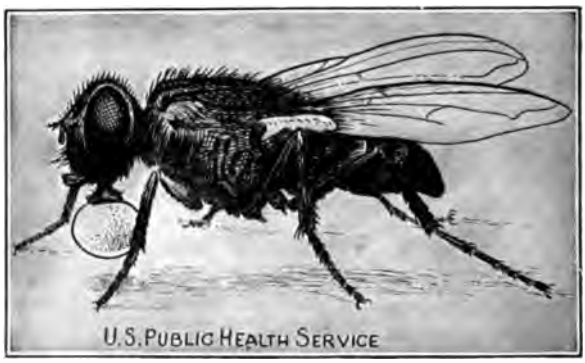

FIG. 336.—A fly regurgitating food and bacteria. (*U. S. Public Health Service.*)

The fly is known to carry disease germs in three different ways: *by carrying them on its body and legs, by regurgitating them, and by leaving them in its fly specks.* Each of these methods requires some special discussion.

1. **The fly's foot** is very well adapted for carrying bacteria. It consists of two sticky pads, two claws, and many hairs which take up bacteria as a brush does paint. Wherever the fly goes the bacteria are left in its foot tracks. The Connecticut Experiment Station found 6,600,000 bacteria on a fly from a swill barrel.

2. **Regurgitation of food** occurs when the fly has had a hearty meal and over eaten. After the fly has fed at the swill barrel, gar-

bage can, privy, or on sputum from a tuberculosis patient it may enter the house and regurgitate some of its stomach contents on food which is to be eaten. Although the thoughts of this are unpleasant, it would do no harm if there were no disease producing bacteria present, as is usually the case; but sometimes harmful bacteria are present. These bacteria may enter the alimentary tract of man or domestic animals and produce disease.

Unlike many other flies the house fly is unable to bite. The stable fly often bites in rainy weather and by many is mistaken for the house fly. The mouth parts of the house fly are unsuited for taking up solid food or for puncturing the skin of a plant or animal. When a fly eats sugar it regurgitates some fluid from its stomach which dissolves some of the sugar crystal. Then it draws the dissolved sugar into its stomach. In view of this fact should a fly be disturbed while it is making a meal at the sugar bowl?

3. **Fly specks** are the excreta deposited by the fly. When a fly is well fed it may deposit 100 specks of regurgitated and fecal matter in a day. The digestive juices of the alimentary canal of the fly are very simple. It has been shown by experiment that many bacteria, including some of those which cause diseases in man, may pass through the alimentary canal of the fly and remain alive and capable of producing disease. The fly's digestive juices are, evidently, not very powerful.

Fly diseases are those which are carried by flies. Of these typhoid fever leads the list. It is wholly preventable and it is a disgrace to any community to have an outbreak (see study No. 52). The germs which cause most all intestinal diseases may be carried by the fly, particularly summer complaint and cholera. In 1914, 140,000 persons suffered from typhoid fever in the United States and 14,000 died of it. Annually 70,000 infants die in the United States of contagious intestinal diseases. Other diseases which are known to be extensively carried by flies are sore eyes, sores, anthrax, spinal meningitis, leprosy, syphilis, gonorrhea, and yaws. Besides these there is good reason to believe that the fly is to some extent a carrier of most of our common contagious diseases, such as tuberculosis, influenza, and smallpox. To what extent the fly carries animal diseases is not *known*, but it is believed to be to a large extent

responsible for the spread of anthrax, cholera, and hoof and mouth disease. It may also carry the eggs of intestinal worms and tapeworms.

FLY CONTROL.—Since fly extermination is impossible all measures must be of the nature of attempts to reduce its numbers. In our large cities much money is spent every year in efforts to reduce the number of flies to a minimum. It is the duty of teachers and students to aid this movement in every possible way.

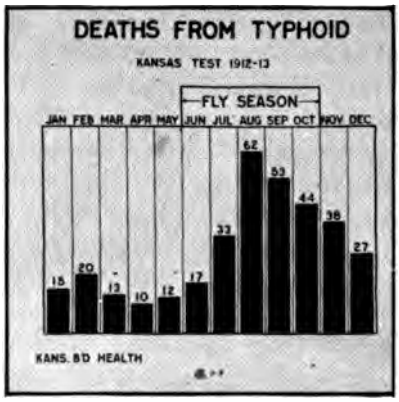

FIG. 337.—A chart showing how the deaths from typhoid fever reach their maximum at the time when flies are most abundant. This is not merely a coincidence; it is a matter of cause and effect. (*From the International Harvester Co., after the Kansas Board of Health.*)

Prevention of breeding is the chief means of fighting flies. If there are no breeding places there will be no flies. Remove all slops, garbage, and manure once a week. Why once a week? Compel everyone to connect with the sewer. In the country the manure may be put on the field daily and spread out to dry, or it may be kept in a tank or bin which is built over a concrete basin which contains water. Under normal conditions, when the larvæ pupate they burrow into the ground, but in this case they fall into the water and are drowned. This will destroy 99% of the fly larvæ. Have a more detailed report given on this subject from Entomology Bulletin *No. 200.*

Poisoning may be done with formaldehyde solution. Put two teaspoonfuls of formalin in ¼ pint of water. Flies require large quantities of water. They will drink this liquid, especially if none other is available, and die. *Keep the poison away from small children.*

Other means of fighting flies are the use of sticky flypaper and swatting. These are both good, but they do not get the fly until it

FIG. 338.—A manure pile maggot trap. The concrete bin beneath the pile contains water in which the maggots drown when they attempt to pupate in the ground. (*U. S. Dept. of Agriculture.*)

is indoors. Traps of many kinds have been made. Flies have no intelligence and will enter a trap readily. Most any moist food is good bait, but fruit, honey, and vinegar have an odor and attract more than foods with little or no odor. Screens are necessary to keep out flies. It has been estimated that we spend $12,500,000 annually for screens against flies and mosquitoes. If we spent one-half this much intelligently fighting them there would be very few of

them, but if we ceased to fight for one year they would be as abundant as ever again. We must keep everlastingly at it.

Project.—Appoint committees to examine the places in your city where food is sold, and estimate the number of flies. Is the food exposed? Are the meat-markets properly screened? Note.—Use proper diplomacy and courtesy in making this survey, but remember that whether you will or not you are fighting a lifelong battle with the fly, and it is a battle to the death. No quarter is ever given by either side.

Community Project.—Secure the lantern slide or chart lecture from the International Harvester Co., Chicago, and invite the public out to an educational lecture on the fly.

Committee Project.—Select two members of the class to go to the City Health Officer with a letter of indorsement from the teacher, and request him to give the class a talk on some timely subject relating to the fly. He will be greatly encouraged in his work if he knows that the schools are with him.

67. ARACHNIDS

What are the relations of spiders, mites, and ticks to man?

Spiders and scorpions are related to insects and crayfish and are thought of as insects by many people, but they differ from both of these groups in some easily recognized particulars. The class ARACHNIDA belongs to the phylum ARTHROPODA which, it should be remembered, also contains the classes INSECTA, CRUSTACEA, and MYRIOPODA. The common arachnids are the spiders, scorpions, harvestmen, ticks, and mites. In these forms the head and thorax are closely united and form one structure called the *cephalothorax* (head-thorax), and there are four pairs of legs. Spiders differ from insects in the particulars noted in the following table.

LABORATORY INVESTIGATION

	Class Insecta *Grasshopper*	**Class Arachnida** *Spider*
Body divisions		
Legs		
Wings		
Mouthparts		
Feelers		
Respiration		

It should be made out by each student from specimens and references.

Spider Webs.—Perhaps the most interesting thing about spiders is their webs which are made from a fluid carried in their abdomens. It is allowed to emerge through minute openings called *spinnerets*. When the fluid comes in contact with the air it dries.

FIG. 339.—Dew on a spider web.

Project.—Observe as many different kinds of spiders as possible and learn for what they use their webs. You will probably be surprised to note the many different forms used for catching prey, but this is only one of the many uses which spiders make of their webs. Make a list of them.

Note to Teacher.—Devote some time to a socialized recitation or round table discussion of spiders and their webs.

Economic Importance.—Spiders, harvestmen, and scorpions are, in general, beneficial. They do practically no harm at all and devour many harmful insects as well as some which are valuable.

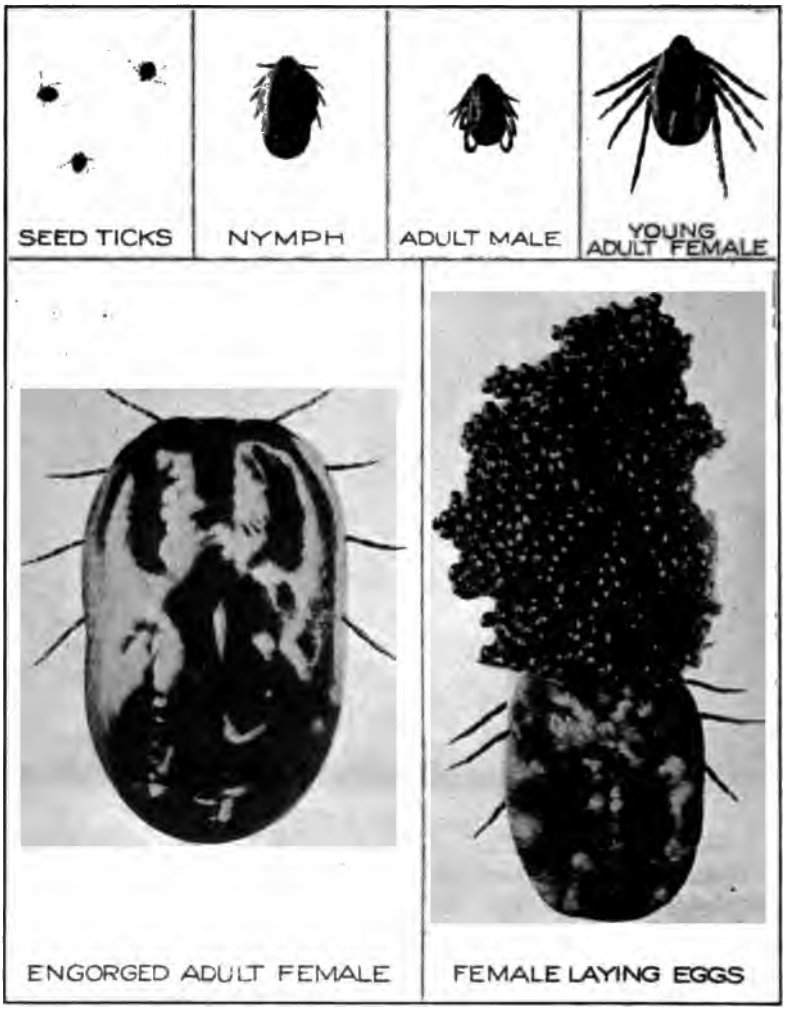

FIG. 340.—The life history of the cattle-fever tick. (*U. S. Dept. of Agriculture.*)

However, not all arachnids are beneficial. The ticks and mites are often very harmful. Some carry disease germs, some are parasites on plants, some live in the water and are parasites on fishes, some

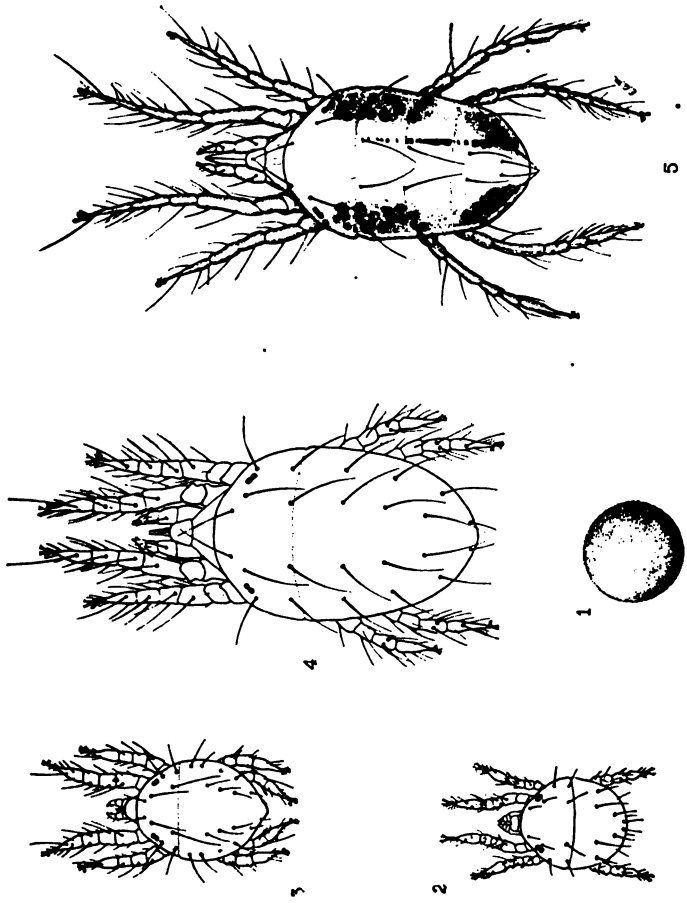

FIG. 341.—The life history of the red spider. 1, egg; 2, newly hatched larva; 3, second stage called the protonymph; 4, third stage called the deutonymph; 5, adult female. (*U. S. Dept. of Agriculture.*)

cause scab and mange in domestic animals, and one causes the seven year itch in man.

The Texas fever tick inhabits the southern part of the United States and other warm countries. It attacks cattle and carries the

germs of Texas fever. This fever has caused an annual loss of $100,000,000. The fever is caused by a protozoan (*Babesia bigeminum*). If a tick attacks an animal which has the fever it will take the microbes into its body. It remains on its host until it is fully gorged with blood when it drops off and develops its eggs. It does not attack a second animal, therefore, the disease is not transmitted by the tick direct; but its eggs harbor the germs and pass them on to the young ticks. When these attack an animal the germs are injected and the disease is transmitted. Prepare a diagram to illustrate the cycle.

Control Measures.—The disease is kept under partial control by the enforcement of a rigid quarantine against the shipment of south-

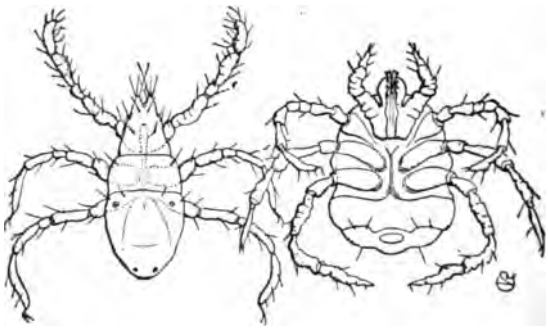

FIG. 342.—The harvest mites or "chiggers," the one with six legs is a larval form and the one with eight is an adult. (*U. S. Dept. of Agriculture.*)

ern cattle. It has been found that by using a system of rotating pastures in such a way that the young ticks will starve for lack of animals to attack the disease can be checked. It is also possible to kill the ticks by subjecting the cattle to a lime-sulphur dip. Southern cattle often have an attack of the fever when they are young, recover, and remain immune thereafter.

The red spider is a parasite of plants. It is bright red in color, very small, and belongs to the group of arachnids known as *mites*. It is known to attack 183 different species of plants in North America. About half of its host plants are domestic. It may do very serious damage to cotton, blackberries, tomatoes, beans, and peas. *It is often confused* with the class of fungus diseases called *rusts*

because of its red color. The red spider is a good example of a parasite which is harbored over winter by weeds. It can be controlled by crop rotation, destruction of weeds on which it winters, and the use of contact sprays.

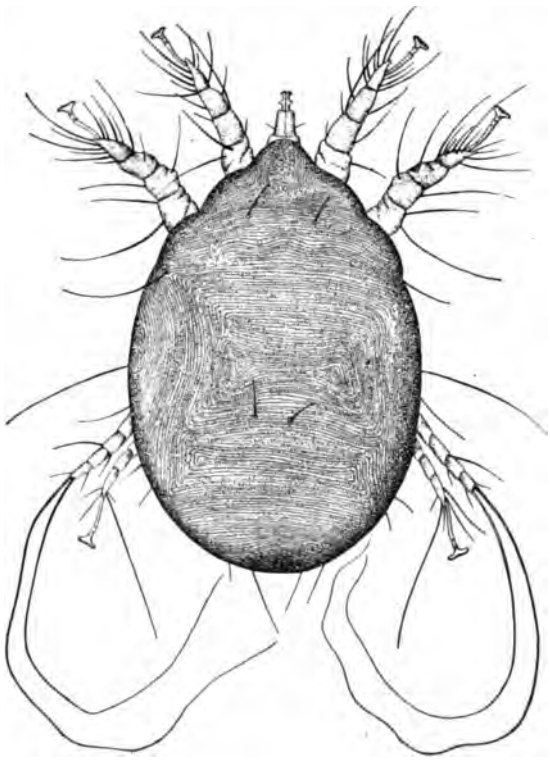

FIG. 343.—The female sheep scab (*Psoroptes communis ovis*) which infests sheep and causes their wool to fall off. An almost identical form affects cattle. (*U. S. Dept.* of *Agriculture.*)

Field Project.—If the red spider is found in your community make a list of the plants on which it is found, and try to find out on what plants it passes the winter. Of what value is such information?

Harvest mites are commonly known as *chiggers* throughout the central states. The adults are small red mites. The young are found on blades of grass where they wait for their host. They may

infest most any animal with which they come in contact and do damage to dogs, cats, birds, cattle, horses, and man. They can be killed easily on man when they first attack by rubbing the affected parts of the body with a cloth moistened in strong alcohol.

Itch mites are arachnids which cause itch in man, scab in cattle, and mange in dogs. Nearly every animal, wild and domestic, is

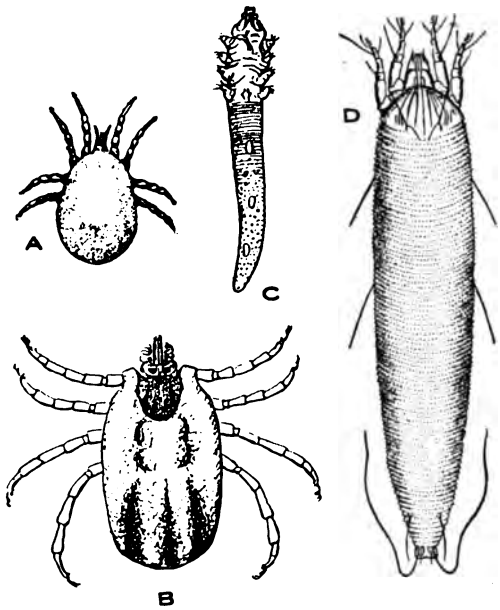

FIG. 344.—Some common arachnid pests. *A*, the poultry tick; *B*, the cattle tick; *C*, the follicle mite; *D*, the leaf blister mite of the pear and apple. (*U. S. Dept. of Agriculture.*)

affected by one or more species of itch mite. Some cause scabs on the skin, and some burrow in the skin and cause severe irritation. Some do great damage to domestic animals and are very difficult to control. Lime-sulphur dip is the remedy most often used, but some species require special treatment.

Follicle mites live in the hair follicles of many mammals. It is almost impossible to destroy them. One form is partly responsible for eruptions on the skin of man.

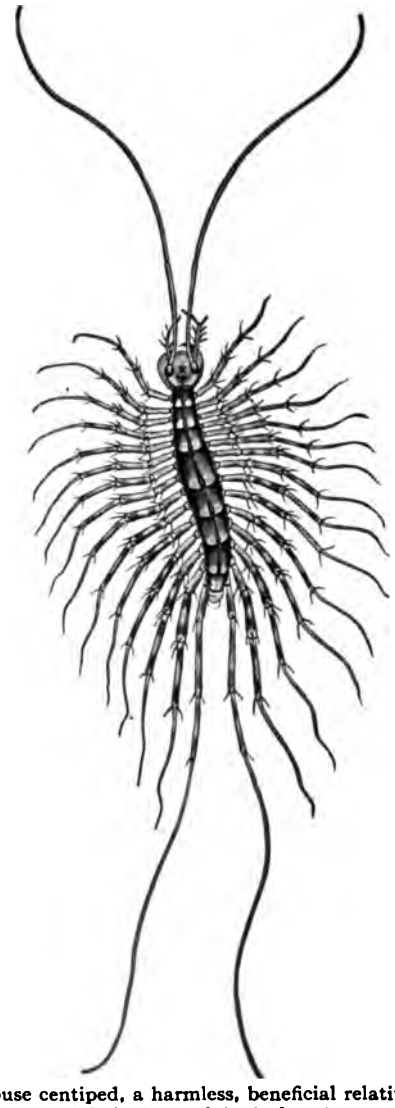

FIG. 345.—The house centiped, a harmless, beneficial relative of the arachnids. (*U. S. Dept. of Agriculture.*)

The poultry mite is found in hen coops. They conceal themselves during the day and attack the fowls at night. They often kill setting hens and are the worst and most abundant of all poultry pests. They can be controlled with whitewash, lime-sulphur, or kerosene emulsion. Cleanliness and rigid sanitation will keep them out when once removed.

Reports.—If time permits, reports may be given on the Rocky Mountain spotted fever tick, the clover mite, and the sheep tick. Consult the latest Farmer's Bulletins from the U. S. Department of Agriculture. The sheep tick is an insect of the order DIPTERA which has lost its wings and has taken up a mode of life like that of the ticks.

Centipeds are many legged, long bodied animals belonging to the class MYRIOPODA. The millipeds are also members of this class and have more legs than centipeds. Their names mean "hundred legs" and "thousand legs."

Laboratory Project.—Obtain some specimens, and count their legs. Are they accurately named?

The house centiped is shown in the illustration. It is perfectly harmless and devours insects which inhabit the house. It is beneficial. Do not kill it.

Laboratory Investigation.—Make a table comparing the centiped and milliped with the spider as follows:

	ARACHNIDA	MYRIOPODA	
	Spider	Centiped	Milliped
Body divisions			
Legs			
Eyes			
Feelers			
Respiration			

68. THE RAT

Why is the rat said to be the most destructive animal in the world?

"*The most destructive animal in the world.*" This is the statement *of David E. Lantz* of the Bureau of Biological Survey, U. S. Depart-

ment of Agriculture. Lantz estimates that on the average each rat destroys $2 worth of produce each year, and that the total annual loss is $200,000,000 in the United States. It requires the labor of an army of 200,000 men to replace this loss. If half were represented by grain destroyed it would require 5,000,000 acres to produce it.

The rat inhabits every continent and most all islands. It crosses oceans, deserts, and mountain ranges.

Problem.—How does it do this?

Its numbers are controlled by the supply of food. When food is abundant rats multiply, and when there is no food they eat each other until the coming of spring. They seek the open fields in the country in summer and feed and multiply freely. In winter they enter barns and granaries where there is plenty. The rat may breed six to ten times a year and produce an average of ten young to the litter. At this rate how many rats will a pair produce in a year? Because all rats do not seek the dwellings of man in the South it is, perhaps, impossible to completely exterminate them in North America. Therefore, the rat will continue to be an eternal enemy of our people. Man has fought the rat for centuries and has devised many ways of killing it. This long struggle has made the rat the most clever of all wild animals, and the most difficult to catch in a trap or to poison.

THE ENDICTMENT.—In our case against the fly we found it guilty on but one count,—*it carries disease germs;* but we can make out many counts against the rat. The only reason why flies kill more people than rats is that they are more numerous.

1. **Rats destroy food.** They eat all sorts of food that man does and offal and garbage besides. They eat the standing grain in the field; the stored grain in bags, bins, or cribs; and the prepared food in stores and houses. They destroy growing ducks, pigeons, and chickens. One rat may destroy all of the young chickens on a farm in a single night. They have been known to attack grown hens when hungry. They destroy young birds and bird's eggs, and may even eat hen's eggs if they are left in the nest over night.

2. **Rats destroy property.** They gnaw holes in the floors of buildings and undermine foundations with their burrows. They dig into the banks of drain ditches and cause caveins. They burrow

through levies permitting the water to run through and flood land. They gnaw lead pipes and flood buildings. They cause fires by gnawing matches. They carry food into buildings and leave it to decay, or they may die and decay between walls where they can not be removed. Besides all this the amount of money spent in making buildings rat proof is considerable.

FIG. 346.—Ears of corn destroyed in the field by rats. (*U. S. Dept. of Agriculture.*)

3. **Rats carry bubonic plague.** In the epidemics of the fourteenth century which swept over Europe, it is estimated that 25,000,000 people were killed. One half of the population of Italy died of it. Grass grew in the streets of London and corpses were left *unburied* when the "black death" ravaged it. This disease is *constantly present* in Asia, Africa, Australia, and South America.

Outbreaks occurred in San Francisco, Seattle, and Hawaii in 1909, in Porto Rico in 1912, and in New Orleans in 1914. These were promptly suppressed by exterminating the rat.

Bubonic plague is caused by a bacterium which is carried from one rat to another by fleas. It is primarily a rat's disease. When a rat dies the fleas leave it and go elsewhere. If an infested flea should bite a person, the disease would be acquired. In exterminating the plague all animals which may be infested by the rat flea must be killed or quarantined. Cats, dogs, squirrels, mice, gophers, prairie dogs,—all must go. The successful fight made by the United States Government against bubonic plague whenever it has made its appearance is one of the most noteworthy achievements of biological science. Only 77 people died of it in San Francisco before it was stamped out. The difference between 77 and 25,000,000 deaths marks the triumph of modern science over mediaeval superstition. In the face of facts like these, who doubts the value of teaching biological science!

Exercise.—Make a diagram of the life cycle of the bubonic plague germs. Put some of the diagrams on the board and compare them in class.

4. **The rat is the natural host of trichina.** We have discussed trichina in study No. 63. When a rat dies, if there is a shortage of food, it is eaten by other rats. Also rats eat the dead bodies of other animals. For these reasons trichina are more often found in the bodies of rats than in any other animals.

5. **Rats carry bacteria on their feet and tails.** Of all homes the rat prefers a drain ditch to any other. They are excellent divers and swimmers. Rats which live in sewers come out at night and spread the germs of typhoid fever, cholera, and other intestinal diseases wherever they go.

Project.—Are any of the sewers or drains in your city infested with rats? Are there any cesspools so constructed that they may be entered by rats?

Since the eggs of tapeworms, round worms, and hookworms are found in sewage they are carried by rats, but to what extent the rat is responsible for the spread of these diseases is not yet fully known.

Coöperation.—We have now found the rat to be guilty on five counts. The student may ask, "If this is all true, why do we permit rats to live?" There are several reasons for their existence. They reproduce rapidly; they are wary of dogs, traps, and poisons; and the public does not realize how dangerous or numerous they are. In the solution of civic biology problems nothing is so important as coöperation. If we are ever to rid ourselves of rats, flies, and contagious diseases we must work together. An ordinance does little good if the public is not educated to its need and organized to aid

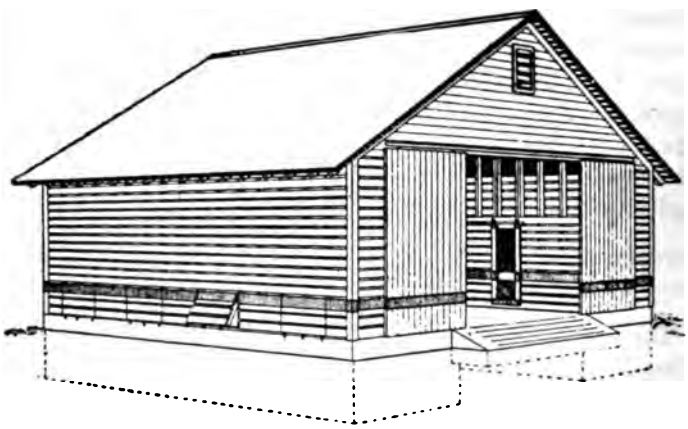

FIG. 347.—A rat proof corn crib with concrete foundation and a metal strip running all around to prevent rats from climbing up the sides. (*U. S. Dept. of Agriculture.*)

in its enforcement. There will always be some who refuse to aid in campaigns for civic betterment. These people are lazy slackers, stingy taxpayers, or ignorant foreigners. They must be made to feel the force of public opinion and do their part.

RAT EXTERMINATION.—After we have killed the last rat we must be ever on the watch for the first one to come into our city or barnyard. Only by persistent effort and eternal vigilance can we keep our city free from rats, *but it can be done.*

1. **Starvation.**—If rats can be kept out of barns, basements, sewers *and other places* where they may find food in the winter time in the

north and central states they can be greatly reduced in numbers for there is little for them to eat in the fields.

2. **Poisons.**—The use of poison is seldom to be recommended. It causes suffering to the rat, the dead bodies give off bad odors, and valuable animals may be killed. Barium carbonate and arsenic are recommended by the U. S. Department of Agriculture as rat poisons. Never use a phosphorous poison. It may cause fire. For methods of using poisons see Farmer's Bulletin No. 896.

3. **Traps.**—The boy who can outwit an old rat and secure him in a trap may well feel proud. Traps requiring bait, except cage traps, are not to be recommended for old rats.

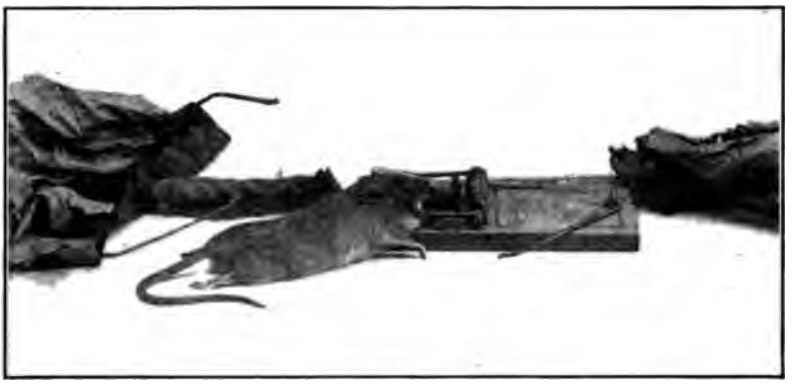

FIG. 348.—A good type of trap for rats and mice. This is a mouse. In some places they do more damage than rats.

The focal method of destroying vermin consists in attracting them to a certain place (a focus) and then destroying them. Feed your rats well every day for a time, then set a trap for them. They are wary of the scent of human beings and will usually avoid a trap that is freshly set or that is not buried. Keep your traps set all the time winter and summer. If you use a cage trap leave the door open and they will go in and out for food. Then close it and let them enter by the trap door.

4. **Cats very seldom kill rats.** Some are actually afraid of them. The tested rat catcher may be of some value, but traps are better.

FIG. 349.—A cat eating a bird. Cats are very inefficient destroyers of rodent pests.

FIG. 350.—A pile of rodent skulls found under an owl roost. Owls do not digest the bones of animals, but regurgitate them. Owls should be protected. (*U. S. Dept. of Agriculture.*)

Cats catch birds, carry disease germs, leave bad odors, harbor fleas and intestinal worms. In fact, in some ways they are worse than rats. All stray cats should be destroyed by the city pond master, and all petted cats should be licensed the same as dogs. Are cats licensed in your city?

Subject for Debate.—Resolved that it is as great a civic necessity to license cats as to license dogs.

Organization.—"A rat and sparrow club in England in three seasons secured the destruction of 16,000 rats and 28,000 sparrows by an expenditure of less than thirty dollars in prize money." "At New Burlington, Ohio a rat hunt took place some years ago in which each of the two sides killed over 8,000 rats, the beaten party serving a banquet to the winners" (Lantz). Have you enough enthusiasm to do something of this kind in your city? There is no better method of educating the general public to the facts of the rat problem.

Other Pests.—Space does not permit us to mention house mice, meadow mice, and gophers. If time permits they may be studied by assignments and reports, or their life history may be studied as a project by direct observation.

69. FISH AND FISHERIES

What are the relations of fish to man?

CLASSIFICATION.—Four great groups of fish have appeared on the earth.

The ostracoderms (Gr. *ostracho* = shell + *derma* = skin) were heavily armoured, fish-like creatures which lived in the seas in paleozoic times. They perished before the close of the carboniferous period.

The dipnoans (Gr. *di* = two + *pneo* = to breathe) were the lung fishes and were closely related to the ancestors of the amphibians. They are nearly all extinct; but three genera remaining; one each in Africa, South America, and Australia.

The elasmobranchs (Gr. *elasmos* = plate + *branchi* = gills) are the sharks and rays. With the exception of one species which lives in Lake Nicaragua (Where is this lake?), they are all marine, and

although quite numerous, they are of little economic importance except as destroyers of other fish.

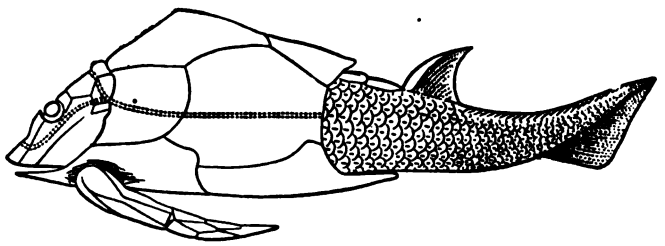

FIG. 351.—Restoration of an ostracoderm. (*Norton, Elements of Geology.*)

The teleostomes (Gr. *teleos* = complete + *stoma* = mouth) are the bony fishes. As their name indicates they have a complete lower

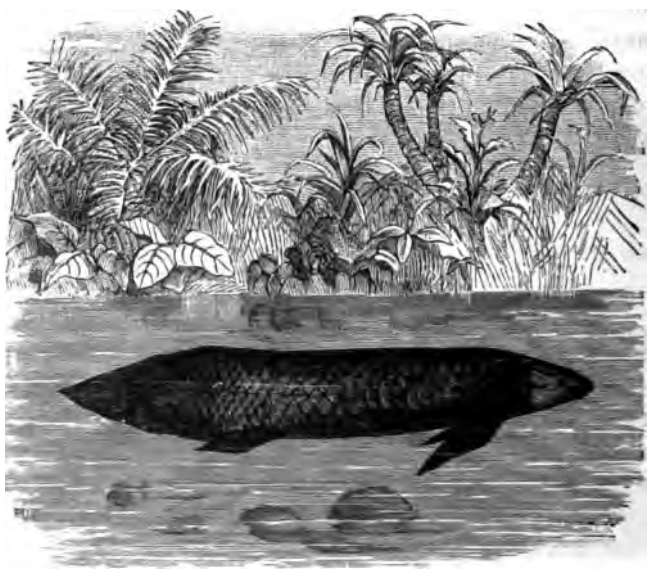

FIG. 352.—The Australian lung fish. (*From Basket, "The Story of the Fishes."*)

jaw. Their gills are covered with an *operculum* (L. a lid), and their *bodies are usually* protected with scales. This group contains

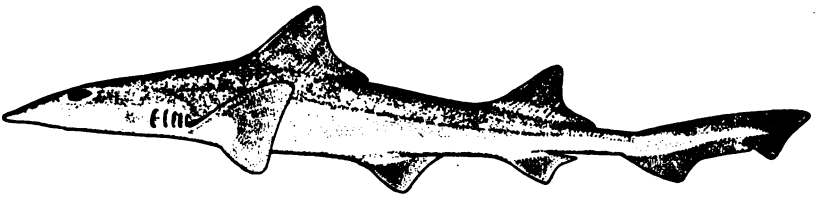

FIG 353.—The dogfish shark. (*Evermann and Radcliffe.*)

FIG. 354.—The common bluegill, a bony fish.

ninety-five per cent of all living fish, and its members are masters of both the salt and fresh waters of the earth to-day.

Natural History.—Because fish live in water—often muddy water—they are not so easily observed as birds and insects; and the average person knows little about them, except how and where they may

FIG. 355.—Sticklebacks and their nest. (*From Basket, "The Story of the Fishes."*)

be caught, and what kinds make good eating. But in reality to those who have an opportunity to study them, their lives are very interesting. In beauty and display of colors some rival the most gorgeous birds and butterflies. In nest building and care of young they have some interesting habits. For instance, there is the male stickleback which builds a cylindrical nest of water weeds and induces a female

to lay eggs in it. These he guards with great heroism until they hatch. If they are well fed and given an opportunity, they will build these nests in the school aquarium. The sunfish and bass make nests by hollowing out cavities in the sand. The male gaff-topsa'l-catfish takes the eggs of the female in his mouth and fasts for ninety days while they hatch. The eggs of the top-water minnow and sharks develop within the oviducts of the mother and the young are brought forth alive. Young catfish remain together for some time after they hatch and are guarded by the male parent.

Migration.—Birds are not the only animals which migrate. The migrations of fish are fully as remarkable. Most boys know how suckers run up the small streams to lay their eggs. The king salmon of our Pacific coast grows to maturity in the ocean and ascends our western rivers to spawn when it is four years old. It lays its eggs in November, and spends the entire summer preceding in ascending the river to its spawning place, often leaping high waterfalls. During the ascent no food is taken, and after spawning the fish floats down stream tail first until it dies. The salmon of the Atlantic coast do not die after spawning but return to the ocean.

The eel reverses this method of migration. It spawns in the ocean and ascends rivers during the growing period of its life. A good account of its life history is given in the National Geographic Magazine of October, 1913, and also in bulletins of the Bureau of Fisheries. Will some member of the class read one of these articles and report on it? Reports may also be made on the migrations of the striped bass, sturgeon, buffalo, and suckers. See bulletins of the U. S. Bureau of Fisheries.

Economic Importance of Fish.—The United States, including her possessions, has about $80,000,000 invested in the industry of fishing. Over 150,000 people are employed in the business, and the products bring an annual return of $100,000,000. Aside from this there is the sport fishing on both salt and fresh water. The great value of this in terms of health, recreation, and food is impossible to estimate accurately. Reports may be given on the methods of taking cod fish, salmon, and herring.

U. S. Bureau of Fisheries.—Fortunately we have not permitted our fish life to be destroyed as has been much of the life of the land,

but the danger is not entirely passed. The several states have laws which protect the fish of their local waters, and the Bureau of Fisheries is doing a great work, both along economic and scientific lines. The United States Government and various states maintain over fifty hatcheries where the eggs are removed from fish by a process called *stripping*. The sperms of the males are placed over them by the same process, and then the entire mass is stirred with the tail of the fish. The adult fishes are then used as food or are returned to the water. The eggs are kept in trays until they hatch, and the young fish are cared for until they are large enough to plant where they are to grow. In 1914 nearly four and one fourth billion eggs and young fish were planted in American waters. Besides this a considerable quantity is shipped annually to foreign countries.

Reports.—Secure the latest bulletins on the subjects from the Bureau of Fisheries and find out what is being done for the lobster, blue crab, oyster, shrimp, and fresh water mussel.

Aquaria.—We have discussed the balanced aquarium before and have shown how the plant and animal life which it contains mutually support each other (Study 14). These facts should be reviewed at this time. Every biological laboratory should have an aquarium. It is convenient to have them built into the building in a well lighted place but where they can be protected from the direct rays of the sun by curtains. Running water is of value in some cases but by no means necessary if the light is suitable to the growth of vegetation. The tank need not be deep but should be wide so as to expose as much water-surface to the air as possible. Why?

Project.—Make up a list of the kinds of fish in your community which can be kept in aquaria. Which kinds can be kept together? Which kinds require running water? What other animals can you keep in the aquarium? What plants? Why do crayfish, some snails, and most insect larvæ die if they are not permitted to come to the surface? An aquarium for keeping crayfish should be very shallow.

Field Trip.—Make collections which will enable you to work out the above projects and others which will present themselves to the interested student and teacher. If you have not done so before make a study of a pond and the life which it contains.

The food of fish varies with the species, the age of the fish, and the season of the year. The eel and carp eat the eggs of other fish; therefore they should not be allowed to become too numerous. Fish without sharp teeth are usually vegetable feeders. Examples of this group are suckers, buffalo, and carp; but these fish eat animal food on occasion for variety. Fish of the bass and pikerel type are almost wholly carnivorous. Very small fish usually feed on vegetable food, minute crustaceans, worms, and insect larvæ. As they

FIG. 356.—An aquarium in the department of biology of the Milwaukee State Normal School. Note that it is broad and shallow. It is at present the home of five turtles, one of which has been in captivity for six years.

get larger the carnivorous forms begin eating minnows which are smaller than themselves. "Big fish eat little fish," but the food problem of fish depends upon the algal life of the water in which they live more than upon anything else, for it is in the green plant tissue that the food of the water world is elaborated, just as truly as is the food of the life of the land. (See photosynthesis, Study 13.) The quantity of fish which a pond will produce is dependent upon the amount of algæ which it can support.

The Fish Pond.—A pond is a balanced acquarium on a large scale. There are many ponds in the United States which are capable of supporting aquatic life of great economic value which are yielding nothing. Get some copies of Bulletin No. 10, Pennsylvania Department of Fisheries, *What an Acre of Water Will Do* and study them. According to this bulletin an acre of water may produce 5,000 to 6,000 pounds of fish per acre per year. What would this quantity of fish be worth? Muskrats, clams, ducks, crayfish, and frogs may also be raised in and around the pond in properly limited numbers and further increase its annual profits.

Debate.—Resolved that water farming is more profitable than land farming.

Project.—Is a pond available where a project of this kind can be worked out in coöperation with the owner? The author will be glad to receive information concerning the results of projects of this kind. Although carp have been domesticated in both Europe and Asia, very little practical, private fish culture has as yet been attempted in America.

70. BIRD LIFE

What are the relations of birds to human life?

Domesticated Birds.—The most important domestc bird is the chicken. It is kept for its flesh, eggs, and feathers by nearly all peoples, and has been bred to conform to many standards of perfection. Its ancestor was the jungle fowl of southern Asia. The dove or pigeon was bred from the rock dove of southern Europe and Asia. It rivals the chicken in variety of forms and colors. It is raised for its attractiveness, its flesh, and for carrying messages. Ducks and geese have been bred from several wild ancestors. The Canada goose and the mallard duck have been tamed many times in North America. They are valued chiefly as holiday table birds. In this respect they are outclassed in the United States by the most recently domesticated of our common fowls, the turkey. This bird was domesticated by the pioneers in North America and has been crossed on a near relative from Mexico. It is still somewhat wild and inclined to wander away from home. The guinea and ostrich came from Africa, and the numerous kinds of pheasants from Asia. There was a time when the falcon was used in hunting and

FIG. 357.—Mallard ducks. These specimens are semi-wild, and it is necessary to keep their wings clipped to prevent them from flying away.

FIG. 358.—The Canada wild goose (brant). All geese, whether wild or domesticated, interbreed.

the Chinese still use the cormorant for catching fish. The parrot, peacock, and canary practically complete the list of domesticated birds.

Note to Teacher.—Have reports prepared and presented to the class on the economic importance and methods of rearing some of the above mentioned birds. Get the latest bulletins on the subjects from the U. S. Department of Agriculture, and use them as references. See the National Geographic Magazine of Dec., 1920 for an account of falconry.

Game Birds.—Man has hunted birds since prehistoric times. In the United States the most prized birds are the turkey, ducks, geese, snipe, woodcock, quail, and partridge. The most abundant game bird of the Continent was the passenger pigeon. The following account of its abundance and destruction is taken from Hegner, quoting from Knowlton's *Birds of the World.*

"The passenger pigeon presents one of the marvels of bird life. A century ago, when the country was new and less settled, this bird, so wonderful for its gregarious habits, existed in flocks of such giganic proportions that the numbers appear absolutely incredible. Thus Wilson, one of America's pioneer ornithologists, writing about 1808, estimated that a flock observed by him near Frankfort, Kentucky, contained not less than 2,230,272,000 birds, and Audubon five years later saw them at Henderson in the same state passing for three successive days in a practically continuous flock; 'the air was literally filled with pigeons, the light of noonday was obscured as by an eclipse,' and the rush of wings was 'with a noise like thunder.' Their nesting places were necessarily of great extent. One described by Wilson near Shelbyville, Kentucky, was several miles in breadth and extended through the woods for upward of forty miles. Every tree of suitable size was loaded down with nests, a large hemlock, for example, often holding from twenty to forty.

"With the advent of the white man in this country, and the blessing of civilization, the war upon the pigeon has been unceasing! Whenever a roosting or nesting place was discovered it was resorted to by a small army of despoilers, and with guns, poles, clubs, sulphur pots, and nets the work of destruction proceeded. Frequently from fifty to one hundred dozen were taken at a single throw of the net. At the large Michigan nesting it was estimated that five hundred

netters were at work and their average catch was 20,000 birds apiece, while for another resort it was estimated that hardly less than 1,000,000,000, including those dead and wounded but not secured, and the myriads of squabs left dead in the nest, were 'sacrificed to Mammon' during a single year."

Among the birds which are now threatened with extinction are the upland plover, wood duck, woodcock, prairie chicken, and Ameri-

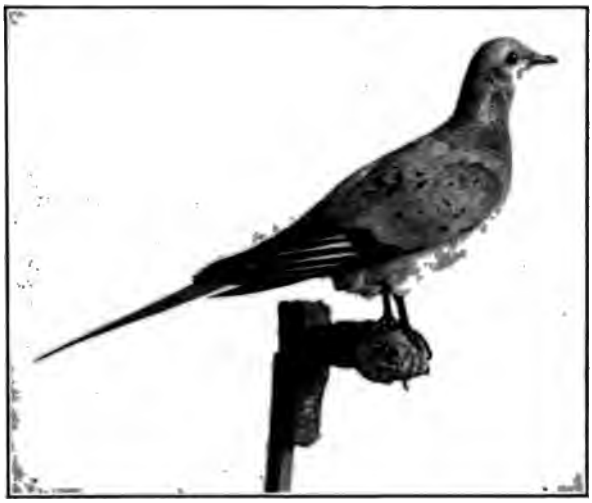

FIG. 359.—The passenger pigeon. (*Photograph, by the author, of a specimen in the Museum of the Milwaukee State Normal School, killed and mounted by Durward in* 1872.)

can eagle. If they are not fully protected and preserves provided for them where they may breed unmolested, they will soon be extinct. An attitude of civic righteousness should be cultivated in the hearts and minds of our people which would make the crime of wanton destruction of wild life a rare and disgraceful offence.

Song birds are of value to man as insect eaters, weed-seed eaters, and as creatures to be studied and loved for their instincts, beauty, and songs. The United States Department of Agriculture has carried out extensive investigations to determine the economic value

of our birds. Hundreds of bird's stomachs have been examined, and the contents carefully noted and recorded. These investigations show that practically all birds are of value, and some are of great economic importance. The crow, sparrow, blue jay, and various hawks and owls have been most severely accused by people who have suffered from their depredations or have observed them in a superficial way. The sparrow was brought to America to destroy insects in our cities. This he does without reward. Last summer the author watched a pair taking green caterpillars from his maple trees all day long, day after day until the insects were gone.

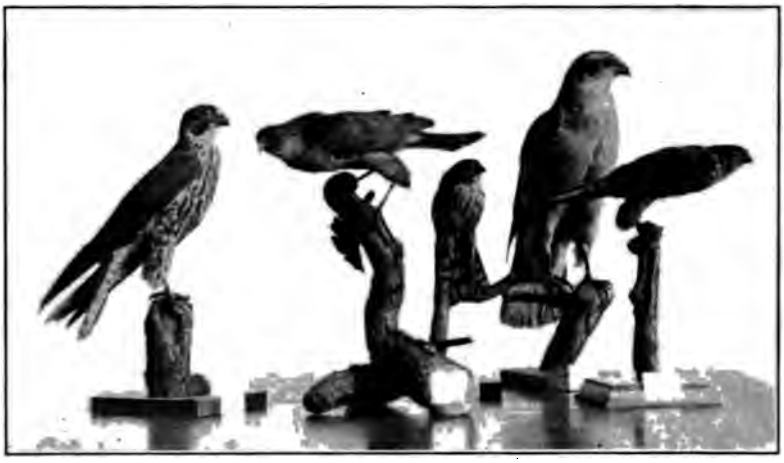

FIG. 360.—Five pernicious hawks. All others are beneficial and should be protected unless they become too numerous. From left to right—duck hawk, Cooper's hawk, sharp-shinned hawk, goshawk, pigeon hawk.

What if they did steal some food from the chicken coop for their babies! They earned it. The author wishes to ask the enemies of the sparrow what bird will take its place and carry on the battle with our insect foes in the city if the sparrow is destroyed? But have no fear he will not be destroyed. Air guns, sling shots, traps, and slanders are all of no avail. Bounties only teach the boys cruelty and make more work for the city clerk. The sparrow thrives and fulfills his mission.

Owls and hawks are mostly beneficial, but the American goshawk, Copper's hawk, and the sharp-shinned hawk are pernicious. The pigeon hawk and the duck hawk are abundant only in certain localities where they probably do more harm than good. The sparrow hawk is a great insect eater but takes a small bird occasionally. Are hawks and owls protected in your state? Is a bounty offered for them? The experience of Pennsylvania with this problem is very interesting.

FIG. 361.—Owls destroy more mice than any other animal which still inhabits the settled districts of the United States except the king snakes and black snakes. Boys should be encouraged to protect owls.

"In 1885, the rural feeling against hawks and owls reached the high-water mark in Pennsylvania. In response to the demands of the farmers of the state, the Pennsylvania legislature enacted a law providing a bounty of fifty cents for the heads of hawks and owls. Naturally, great slaughter of these birds ensued. In two years, 180,000 scalps had been brought in and $90,000 had been paid out for them.

"The awakening came even more swiftly than the ornithologists expected. By the end of two years from the enactment of 'the hawk law,' the farmers found their fields and orchards throughly overrun by destructive mice, rats, and insects; and again they went clamoring to the legislature, this time for the quick repeal of the law. With all possible haste this was brought about; but it was estimated by competent judges that in damages to their crops 'the fool hawk law' cost the farmers of the state of Pennsylvania more than $2,000,000" (Hornaday).

FIG. 362.—A cat at a bird box. Place your bird boxes where cats can not get at them.

Bird Protection.—Much progress has been made along this line in recent years, but much remains to be done. The class should get into communication with the National Audubon Societies, and the American Ornithologists Union. They can help you, and you can help them. A migratory bird law has been passed and a treaty with Canada ratified. Will some student report on the details to the class? See Bulletin No. 785, *Federal Protection of Migratory Birds*. It is now unlawfull to import the plumage of wild birds into the United States, and the slaughter of birds for the decoration of the hats of thoughtless or heartless women has been checked, but

it still goes on in some countries south of the Untied States which are not under our jurisdiction but where our migratory birds go.

Cats are the greatest enemies of our small birds. The keeping of cats should be discouraged by education, and those who feel that they must keep a cat should be required to pay for a license, and to attach a bell to the cat's neck to frighten birds in summer. Fortunately the number of cats and dogs which are kept in cities is decreasing. Most people have come to the conclusion that they are not worth their keep.

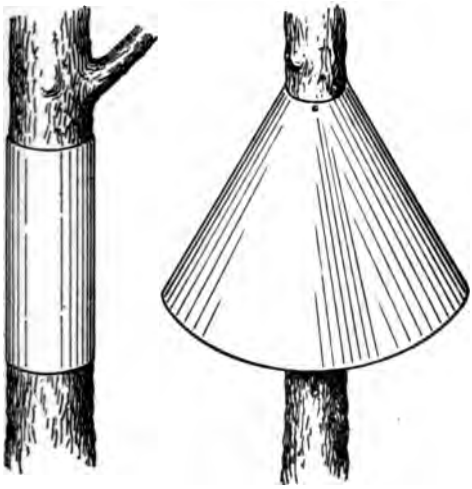

FIG. 363.—Two types of cat guards on trees. (*U. S. Dept. of Agriculture.*)

FIG. 364.—Sumach berries remain on the shrubs all winter and are eaten by seventy-six species of birds.

Attracting birds to our homes, parks, and orchards is an enjoyable pursuit which is becoming more and more popular. The class should appoint committees to set up a bird bath, or two, drinking fountains, and, in the winter, feeding tables may be arranged for our winter residents. Try to secure photographs of the birds as they come to these places. Hunt out their nests and place cat guards around the trees to protect the young. Photograph the nests and young, and try to have the photographs published. Many kinds of shrubs

which produce berries can be planted to furnish both homes and food for birds which do not readily nest in cities. The following list of small fruits is taken from Bulletin No. 715 of the Buraeu of Biological Survey.

Common name	Scientific name	Number of species of birds known to eat the fruit	Common name	Scientific name	Number of species of birds known to eat the fruit
Juniper; red cedar	*Juniperus*	36	Pepperberry	*Schinus*	10
Greenbrier	*Smilax*	38	Holly	*Ilex*	38
Bayberry	*Myrica*	64	Supple-jack	*Berchemia*	12
Hackberry	*Celtis*	38	Buckthorn	*Rhamnus*	16
Mulberry	*Morus*	52	Grape	*Vitis*	71
Pokeberry	*Phytolacca*	48	Virginia creeper	*Parthenocissus*	39
Barberry	*Berberis*	10	Buffaloberry	*Shepherdia*	13
Spicebush	*Benzoin*	17	Wild sarsaparilla	*Aralia*	14
Sassafras	*Sassafras*	15	Dogwood	*Cornus*	79
Currant; gooseberry	*Ribes*	30	Sour gum	*Nyssa*	36
Strawberry	*Fragaria*	42	Bearberry	*Arctostaphylos*	12
Raspberry; blackberry	*Rubus*	114	Huckleberry	*Gaylussacia*	30
Rose	*Rosa*	17	Blueberry	*Vaccinium*	62
Mountain ash	*Sorbus*	14	Mexican mulberry	*Callicarpa*	10
Chokeberry	*Aronia*	13	Partridge berry	*Mitchella*	10
Red haw	*Crataegus*	30	Elder	*Sambucus*	101
Juneberry	*Amelanchier*	38	Snowberry	*Symphoricarpos*	22
Cherry; plum	*Prunus*	66	Black haw	*Viburnum*	26
Sumac	*Rhus*	76	Honeysuckle	*Lonicera*	15

Bird Boxes.—In Farmer's Bulletin No. 609, *Bird Houses and How to Build Them*, we find 27 birds listed which may build their nests in bird boxes. Each bird has its preferences as to what kind of a box it builds in. Dimensions of the nesting boxes which are preferred by each of the 27 species are stated in a table in the above mentioned *bulletin*. How many of the members of the class have bird boxes?

Has anyone any interesting experiences to relate concerning them? Girls should be as much interested in bird boxes as boys. Can you make some boxes in the manual training department? The author visited a school a short time ago where all boys in the school system were invited to make bird boxes and exhibit them. The public was invited in to see them, and the best ones were awarded prizes. Would this be feasable in your school? If so, appoint a committee to investigate ways and means of making it a success.

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